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19th Forum on the Geology of Industrial Minerals

Guidebook for Field Trips

edited by
S.E. Yundt

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W. T. Foster
Deputy Minister

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FOREWORD

19th FORUM ON THE GEOLOGY OF INDUSTRIAL MINERALS GUIDEBOOK FOR FIELD TRIPS

The 2 field trips, to examine industrial mineral deposits in southern Ontario, are intended to complement the wide-ranging selection of papers presented at the "19th Forum on the Geology of Industrial Minerals", held in Toronto, Ontario.

This guidebook has been prepared with 2 objectives in mind: it is intended to serve as a field guide to the geology that will be observed by delegates during the 2 days of excursions; and it is hoped that the information in the guidebook will be of interest to those who are unable to participate in the field trips.

E.G. Pye
Director
Ontario Geological Survey

PREFACE

It is an honour and distinct pleasure for me to welcome delegates of the "19th Forum on the Geology of Industrial Minerals" to Ontario. The field trips have been planned to provide a sampling of Ontario's distinctive geology as well as an introduction to some of the industrial minerals produced here.

The distribution of Precambrian, Paleozoic, and Quaternary deposits has had an impact on the character of development in the southern parts of the province that will be visited, east and west of Toronto. There has been a growing awareness in recent years that we must develop and preserve mineral resources for the use of future generations as well as for our present needs. The field trips will provide you with an opportunity to observe the effects of this recognition in the current mining and rehabilitation practices of Ontario's industrial minerals producers.

I hope that you will find this guidebook a useful background to the geology of the places visited and that you will enjoy the excursions.

S.E. Yundt
Chairman
19th Forum on the Geology of Industrial Minerals

CONTENTS

Page

INTRODUCTION 1

FIELD TRIP A: Industrial Mineral Industries (Talc and Nepheline Syenite)
by D.G. Minnes, W.J. Logan, and E.V. Sado 3

FIELD TRIP B: Industrial Mineral Industries (Aggregates, Stone, and Glass)
by D.W. Scott and S.E. Yundt 21

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If the reader wishes to convert imperial units to SI (metric) units or SI units to imperial units the following multipliers should be used:

CONVERSION FROM SI TO IMPERIAL			CONVERSION FROM IMPERIAL TO SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
			LENGTH		
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709 7	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
			AREA		
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
			VOLUME		
1 cm^3	0.061 02	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.308 0	cubic yards	1 cubic yard	0.764 555	m^3
			CAPACITY		
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
			MASS		
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 908 8**	t
			CONCENTRATION		
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

1 ounce (troy)/ton (short)	20.0	pennyweights/ton (short)
1 pennyweight/ton (short)	0.05	ounce (troy)/ton (short)

NOTE—Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries published by The Mining Association of Canada in cooperation with the Coal Association of Canada.

19th Forum on the Geology of Industrial Minerals

Guidebook for Field Trips

Introduction

Ontario is fortunate to possess many of the important industrial minerals needed for the construction, chemical, and manufacturing industries of the province. One has only to observe the buildings in a city such as Toronto, to appreciate the diversity of the industrial minerals that satisfy our needs and their impact on the way we live.

One of the many benefits of the annual "Forum on the Geology of Industrial Minerals" has been the opportunity afforded delegates to learn how people in different parts of the United States, and elsewhere, have used the available mineral resources to their advantage and developed them to meet a multitude of needs.

The places to be visited and the routes to be followed on the field trips during the 19th Forum will provide insight into the impact of the geology on regional development of this part of Canada.

The talc mine at Madoc has operated continuously for 87 years; and the nepheline syenite deposits of Methuen Township have had a world-wide impact on the types of feldspathic minerals used by many industries.

The pits and quarries to be visited show how aggregate and stone resources have been developed to meet the ever-growing needs of a major metropolitan area, as well as the smaller surrounding municipalities. The progressive rehabilitation of pit and quarry lands to alternative beneficial uses will also be evident.

The trip includes a particularly interesting visit to the glass plant at Milton, where industrial minerals from Canada and the United States are blended to manufacture a wide variety of beverage containers.

FIELD TRIP A

Industrial Mineral Industries (Talc and Nepheline Syenite)

by

D.G. Minnes, W.J. Logan, and E.V. Sado

CONTENTS

	Page
GENERAL	5
TORONTO TO TRENTON	5
TRENTON TO MADOC	7
Stop 1: Madoc Talc Mine	8
History	8
Geology	9
Orebodies	9
Mining and Milling	10
MADOC TO HAVELOCK	11
Stop 2: Nepheline Syenite Mines	11
History	11
Geology	12
Mining and Milling	12
End Uses	15
Quality Assurance	17
Transportation	17
Rehabilitation	17
BLUE MOUNTAIN TO TORONTO	17
REFERENCES AND SELECTED BIBLIOGRAPHY	19

TABLES

1. Table of formations for Methuen Township (from Hewitt 1961)	14
2. Typical product analysis of nepheline syenite (courtesy of Indusmin Limited)	17
3. Indusmin Limited nepheline syenite basic product range (courtesy of Indusmin Limited)	18

FIGURES

1. Physiographic map of southern Ontario, showing routes for Field Trips A and B	6
2. Henderson orebody and neighbouring talc deposits (after Simandl and Ogden 1982)	9
3. Typical, vertical section through Henderson deposit (after Simandl and Ogden 1982)	10
4. Structural map of Methuen Township (from Hewitt 1961)	13

PHOTOGRAPHS

1. Mill and head frame, Canada Talc Industries Limited, Madoc	8
2. Nepheline syenite plant, IMC Chemical Group (Canada) Limited, Blue Mountain	12
3. Nepheline syenite mine, IMC Chemical Group (Canada) Limited, Blue Mountain	15
4. Nepheline syenite mine, Craig Pit, Indusmin Limited, Nephton	16
5. Nepheline syenite plant, Indusmin Limited, Nephton	16

FIELD TRIP A

Industrial Mineral Industries (Talc and Nepheline Syenite)

by

D.G. Minnes[1], W.J. Logan[2], and E.V. Sado[3]

GENERAL

This field trip will take us on a round trip of 585 km. From Toronto we will travel eastward towards Trenton, over glacially modified terrain. From Trenton we will travel north to a talc mine, passing over the Paleozoic contact with Grenville age rocks. The drive to the nepheline syenite mines will take us mainly through an area where thin limestone beds overlie the gently undulating surface of the Grenville. On our journey back to Toronto we will pass through an area of limestone which is mainly covered by fine examples of glacial drift, drumlins, and moraines.

Regional data on the surficial and bedrock geology of southern Ontario and notes on the talc and nepheline syenite mines are given in this field trip guidebook. In addition to these notes, participants on the field trip will receive the map entitled "Physiography of the South Central Portion of Southern Ontario" (Chapman and Putnam 1972), additional detailed notes on the mines being visited, and a general brochure on Toronto's geological past (Freeman 1976) that provides details of the geology in the Toronto area.

Participants are advised to follow the route shown in Figure 1, noting comments in the road log below. All distances are measured in kilometres from the hotel near the Toronto International Airport, Madoc, and Blue Mountain, respectively.

[1]Policy Analyst, Industrial Minerals Section, Mineral Resources Branch, Ontario Ministry of Natural Resources, Toronto.

[2]Regional Mines Coordinator, Algonquin Region, Ontario Ministry of Natural Resources, Huntsville.

[3]Supervisor, Quaternary Geology Subsection, Engineering and Terrain Geology Section, Ontario Geological Survey, Ontario Ministry of Natural Resources, Toronto.

TORONTO TO TRENTON

Highway 401 between Toronto and Trenton crosses 3 distinct physiographic regions known as the South Slope, the Peel Plain, and the Iroquois Plain. The South Slope is the southern slope of the land off a massive glacial deposit known as the Oak Ridges Interlobate Moraine, 244 to 304 m (800 to 1000 feet) above sea level (a.s.l.) to the north, and the Iroquois Plain, 122 m (400 feet) a.s.l. to the south. The Peel Plain is a sloping tract of clay soil with a 152 to 229 m (500 to 750 feet) elevation a.s.l. within the South Slope that was occupied by postglacial Lake Peel. The Iroquois Plain is the lowland bordering Lake Ontario which was covered 12 000 years ago by postglacial Lake Iroquois (Figure 1).

0-23 km Highway 401, from the hotel to just past the Don Valley, follows along the southern margin of the Peel Plain. This level to undulating landscape is named after glacial Lake Peel which deposited a thin (0 to 9 m) layer of clay soil over glacial till. Glacial Lake Peel was impounded by a glacier to the south which occupied the Lake Ontario basin and higher land (Oak Ridges Moraine) to the north.

19 km *Don River Valley.* The Don is 1 of 2 major river valleys (the other is the Humber) which had a major effect on the growth and development of Toronto. These rivers occupy deep (up to 30 m in places) broad valleys which have hampered the expansion of the city. Both valleys are controlled by the Metropolitan Toronto Conservation Authority, which has constructed a series of parks and water control dams along them. The Humber River was in the main path of Hurricane Hazel on October 14-15, 1954, during which time 20 cm of rain fell. The resulting flood caused extensive property damage and loss of life along the river channel.

Between Toronto and Trenton many such rivers have carved deep ravines into the glacial overburden.

23-34 km Just east of the Don Valley we will travel through a drumlinized till plain; this is part of the South Slope. Note that at the Meadowvale Road exit, the borrow

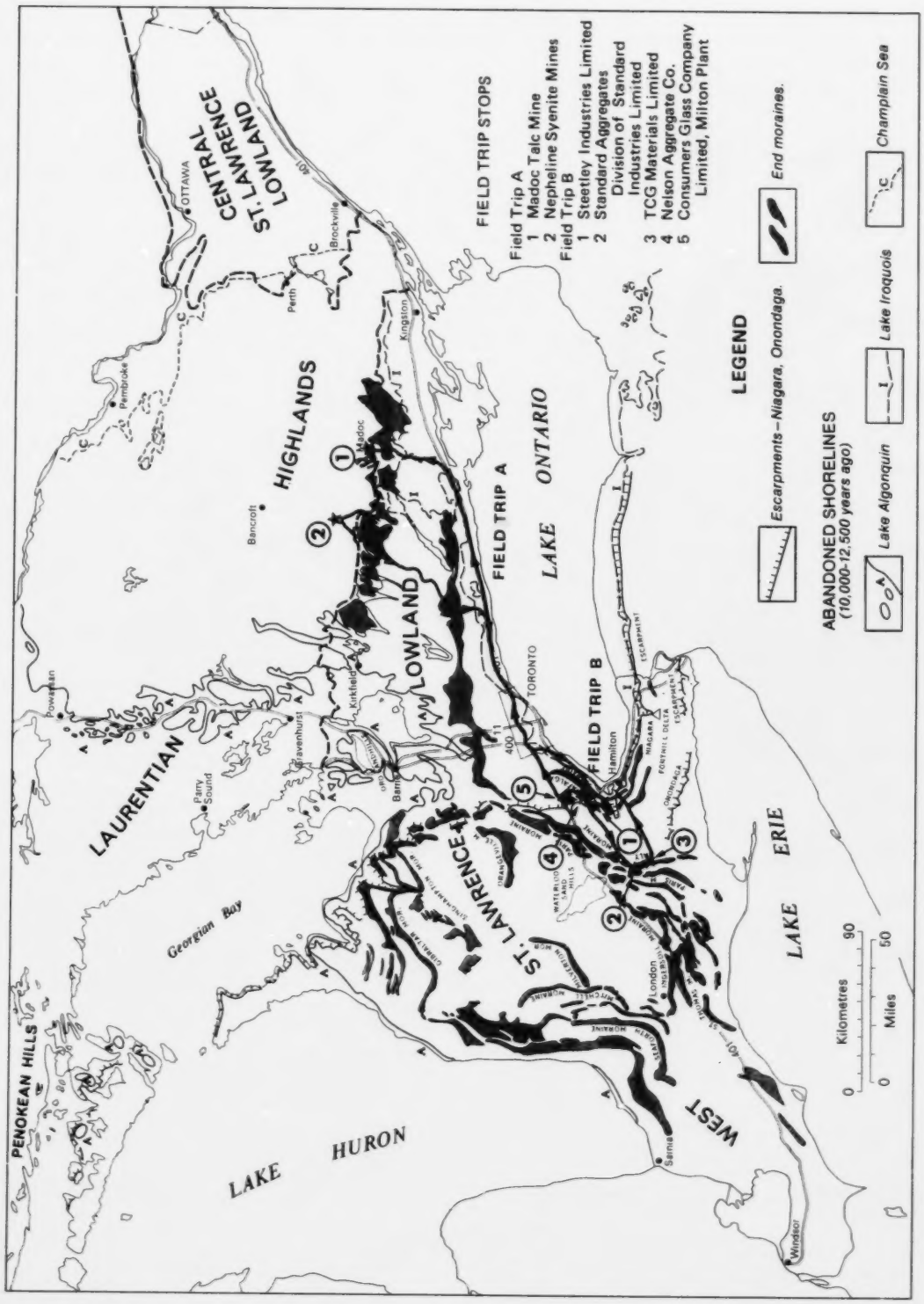

Figure 1—Physiographic map of southern Ontario, showing routes for Field Trips A and B.

for a landfill site is visible on the horizon to the north. This is near the Metropolitan Toronto Zoo.

34-200 km Highway 401 descends onto the Iroquois Plain. This lowland bordering Lake Ontario was occupied by glacial Lake Iroquois about 12 000 years ago. The old shoreline of this lake, including cliffs, bars, beaches, and boulder pavements follow more or less the route of Highway 401 from here to Trenton. From time to time the Highway will climb out of this lake plain onto the drumlinized till plain of the South Slope.

80 km Drumlins from the till plain beneath the sands and clays of Lake Iroquois show up well in places. Terraces marking the water plain of this glacial lake are notched into the flanks of some drumlins.

97 km Good view of Lake Ontario to the south with occasional bedrock exposed along the shore (Lindsay Formation - limestone).

105 km *St. Marys Cement Limited plant, Bowmanville.* The quarry and cement plant are located on the south side of Highway 401 and Canadian National Railway tracks. The Bowmanville plant is located here due to optimum conditions for overburden thickness and stone quality. The plant, constructed in 1967, produces 680 000 tonnes per year. It is a 2 kiln, wet process plant. Overburden at the quarry ranges from 6 to 11.5 m in thickness and is composed of glacial till overlain by the varved clay of Lake Iroquois. The till is highly compacted and presents some excavation problems. The quarry is worked in 2 benches to a depth of 21 m. The upper bench (4 to 6 m) consists of argillaceous limestone of the Whitby (Collingwood) Formation. The average analysis of this stone given by the Company is as follows: loss on ignition 33.4%; silica, 16.8%; iron oxide, 1.7%; alumina, 5.5%; and lime, 46.3%. The lower bench (17 m) consists of Lindsay Formation limestone which is microcrystalline to finely crystalline, calcilutite to calcarenite. An average analysis is: loss on ignition, 37.6%; silica, 9.9%; iron oxide, 1%; alumina, 3.4%; and lime, 46.3% (Hewitt and Vos 1972).

128 km *Gas station on south.* Here, there are several abandoned gravel pits within the Lake Iroquois beach deposits.

131 km *Good view of skyline of the Oak Ridges Moraine (300 m a.s.l.) to the north.* Note the very irregular hummocky surface of kame deposits in the moraine. We will travel across the moraine on our return trip via Highway 115.

137 km *Port Hope, business exit.* Note the gravel pits in Lake Iroquois beach deposits.

150-200 km *Cobourg, Highway 45 exit.* Travelling in an easterly direction from here, Highway 401 roughly follows the former Lake Iroquois beach and shoreline. Note the gravel pits and drumlins.

200 km From Highway 401, exit onto Highway 33 and proceed north to Madoc. Note the abundant bedrock exposures in the roadcuts and along the Trent River (Verulam Formation - shaley limestone).

TRENTON TO MADOC

200-207 km Highway 33 follows the west bank of the Trent River. The Trent is the largest river in southern Ontario. Its headwaters originate within the Precambrian Shield. The Trent's lower course is on Paleozoic limestone, which in this region is covered by very little glacial overburden. Along the Trent River system numerous lakes (Kawartha Lakes) occur along the contact between the Paleozoic limestones and the crystalline rocks of the Canadian Shield. These lakes occupy portions of preglacial valleys, which were further deepened by glacial ice action. The lakes of this chain drain into one another in a zigzag pattern over the lowest saddles in the bedrock. Glacial Lake Algonquin drained into Lake Iroquois via this system, and as a consequence the valley is very broad and rock floored. The many lakes, broad reaches, and marshy areas to the north contrast sharply with the rapids and waterfalls along this stretch of the Trent River.

In the late 1800s a canal was constructed to link Lake Huron and Lake Ontario via the Trent-Severn River system. The distance along this waterway, from Lake Ontario at Trenton to Port Severn on Lake Huron, is 386 km; there are 43 locks. The canal system is still used today, mainly for pleasure craft. The Kawartha Lakes region along this canal is one of Ontario's most accessible and scenic recreational areas. You will note the many small hydroelectric power generating plants along this stretch of river which have attracted many small industries to locate nearby.

207 km *Frankford.* Highway 33 crosses the Trent River and we continue along the east bank to Stirling. As we cross the river, note the Frankford esker which was breached by the river during postglacial drainage of Lake Algonquin.

223-229 km *Stirling to Highway 62.* The road follows along the crest of an esker. Note the drumlinized till plains on either side and an abundance of gravel pits within the esker. Many eskers in southern Ontario have been totally removed because of the demand for sand and gravel.

229 km *West Huntingdon.* Turn left on Highway 62 to Madoc. Note the roadcuts exposing the Verulam Formation, consisting of limestone, as well as the gradual transition of the landscape from drumlinized till plain to the Dummer Moraine.

234 km *Ivanhoe.* Here, there is an abrupt change of landscape and land use, from farmland on the till plain to the south, to rough stony land used for woodlands with limited pasture. This is the Dummer Moraine which borders the Precambrian Shield to the north. Glacial ice, advancing from the north over crystalline bedrock, suddenly encountered the softer more brittle Paleozoic limestones along the contact. The ice rapidly became supercharged with the local limestone and when it stagnated, it discharged the limestone debris in this fashion. (The origin of the Dummer Moraine is still considered somewhat problematic.) This landscape is characterized by large angular blocks of local limestone, deposited randomly in pockets on the surface.

245 km *Precambrian inlier along the south shore of Moira Lake just before entering Madoc.*

250 km The Village of Madoc has been the centre of mining activity for over 100 years. In 1837, a furnace for smelting local iron ore was opened in Madoc. In 1866, the first gold discovery in Ontario was made nearby at Eldorado, and many other gold, as well as lead and copper discoveries, followed. Fluorspar mining began at Madoc in 1905. Thirty-one fluorspar and a few barite deposits were opened in the area. Talc was discovered in 1896 and has been produced here since that time. Marble was quarried as early as 1900. Since 1936 a permanent marble chip industry has been established. Approximately 20 marble quarries in the vicinity are the source of multicoloured crushed products for the terrazzo industry. Slate was quarried in the past and roofing granules are still quarried nearby from an ultrabasic intrusive.

Stop 1: Madoc Talc Mine

We will visit the operations of Canada Talc Industries Limited at Madoc, Ontario (Photo 1). Much of the following description is from Hewitt's (1972) report on "Talc in Ontario" and from G.J. Simandl (Graduate Student, Carleton University, Ottawa, Ontario, personal communication, 1982).

HISTORY

Canada Talc Industries Limited operates the Henderson and Conley talc Mines at Madoc. Talc was discovered at Madoc in the 1880s, not far from the shore of Moira Lake, just east of the town, and in 1896 the Henderson Mine commenced production. The Henderson Mine has operated continuously since 1896. The Conley Mine, discovered in 1911, is a northeastward extension of the Henderson orebody and production began in 1912.

The properties were merged in 1937 and operated as Canada Talc Limited until 1951, when they were purchased by Canada Talc Industries Limited. William R. Barnes Co. Limited of Waterdown, Ontario, purchased the company in 1981.

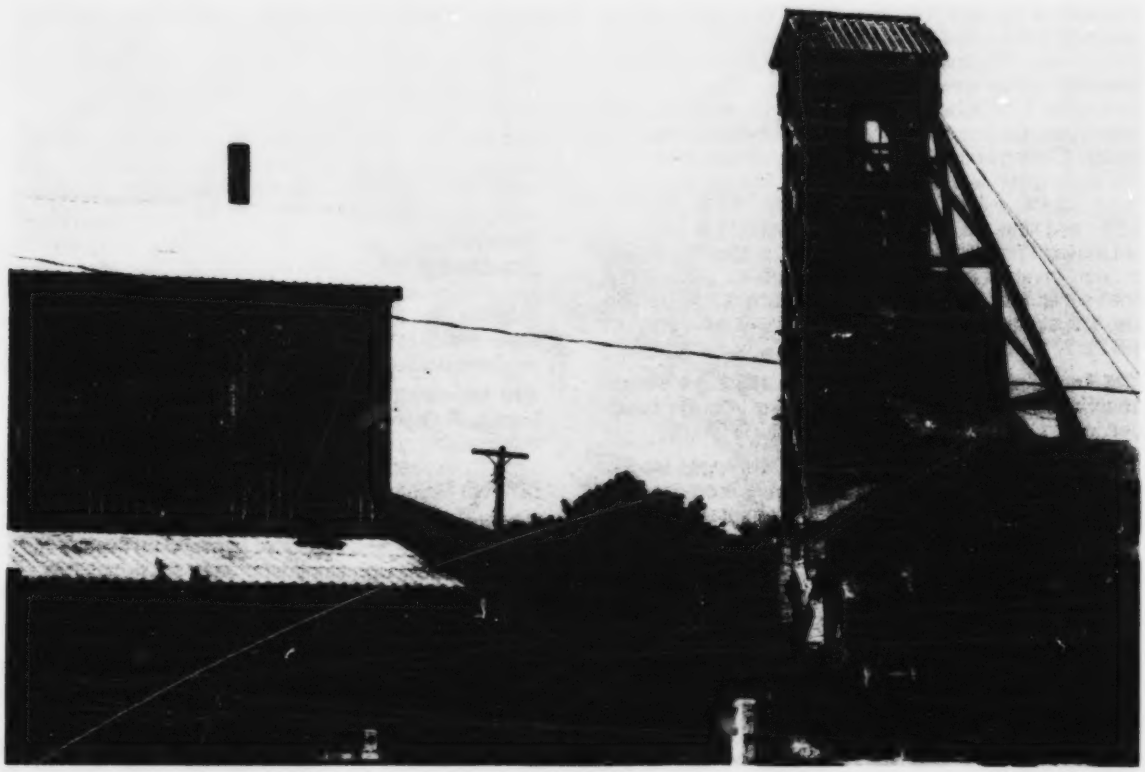

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Photo 1—Mill and head frame, Canada Talc Industries Limited, Madoc.

GEOLOGY

The talc orebodies occur in Grenville crystalline dolomite of Precambrian age. The Grenville formations in the vicinity of the mine consist of tremolitic crystalline dolomite and dolomitic limestone, interbanded quartzite and crystalline dolomite, quartzite, and talc mica schist. The regional structure appears to be anticlinal with the anticline steeply pitching to the southwest. Strong drag folding and crenulation can be observed on both limbs of the anticlinal fold. Its crest appears to be just west of the former Henderson open pit (Figure 2).

The talc occurs as tabular hydrothermal replacement bodies in the crystalline dolomite. The conformable sheet-like talc deposits are thought to have been formed from the dolomite by the introduction of siliceous solutions from the nearby Moira granite, that entered fractures and faults on the south limb of the anticline and altered the dolomite first to tremolite and then to talc. Evidence of this dolomite-tremolite-talc transition can be seen in thin sections of specimens from the deposit. Subsequent folding and faulting is responsible for the crenulation, thickening, and offsetting of the talc ore sheets.

Grenville metasediments were cut by mafic dikes which were named "madocite" by Wilson (1926). These dark coloured dikes consist predominantly of black tourmaline, amber mica, tremolite, and plagioclase with minor amounts of pyrite, arsenopyrite, quartz, actinolite, titanite, apatite, and zircon. Hewitt (1972) suggested that the dikes were emplaced prior to the local faulting, as some are displaced by faulting and are folded in the same way as some of the Grenville metasediments.

A very interesting discovery was made in 1982 when the new East open pit orebody was being readied for mining. A portion of the talc deposit was still covered by a thin capping of Paleozoic limestone. When this capping was removed a "madocite" dike was discovered. This dike had evidently been subjected to considerable Precambrian weathering prior to the deposition of the limestone. A very deep, earthy profile has been developed in the dike with characteristic oxidation products.

OREBODIES

Canada Talc Industries Limited currently mines high

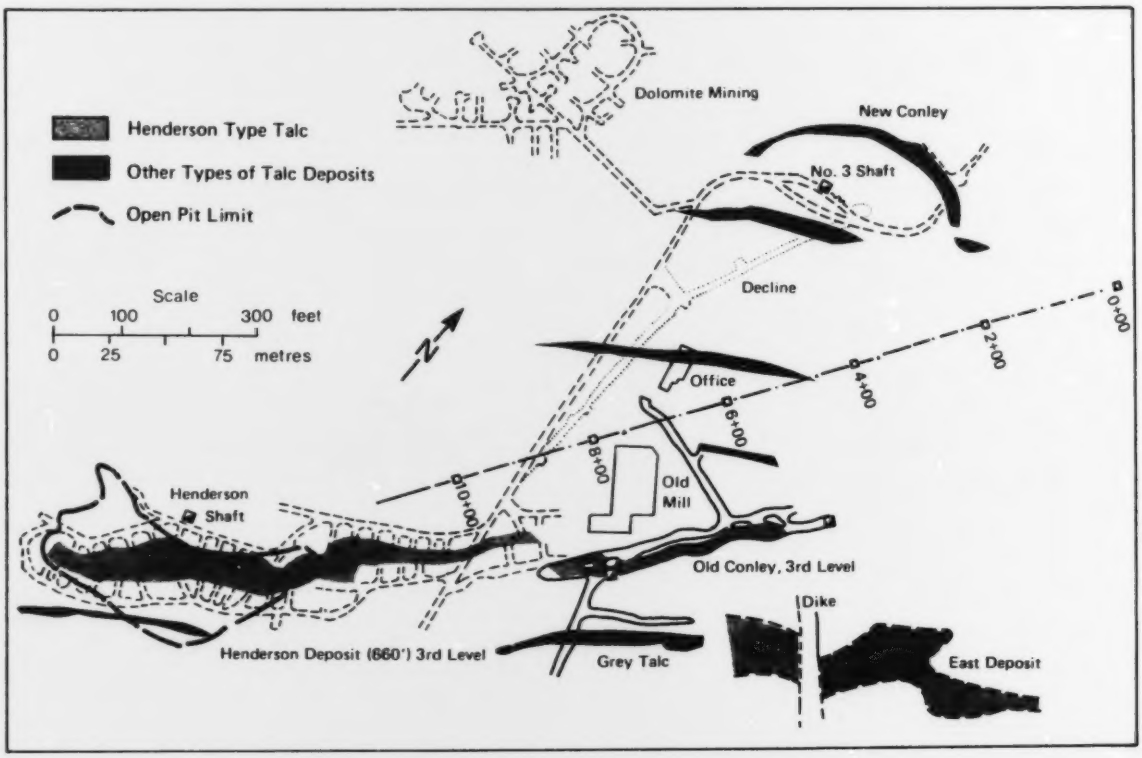

Figure 2—Henderson orebody and neighbouring talc deposits, compiled from company documents, Sandomirsky (1954), and mapping and drilling (after Simandl and Ogden 1982).

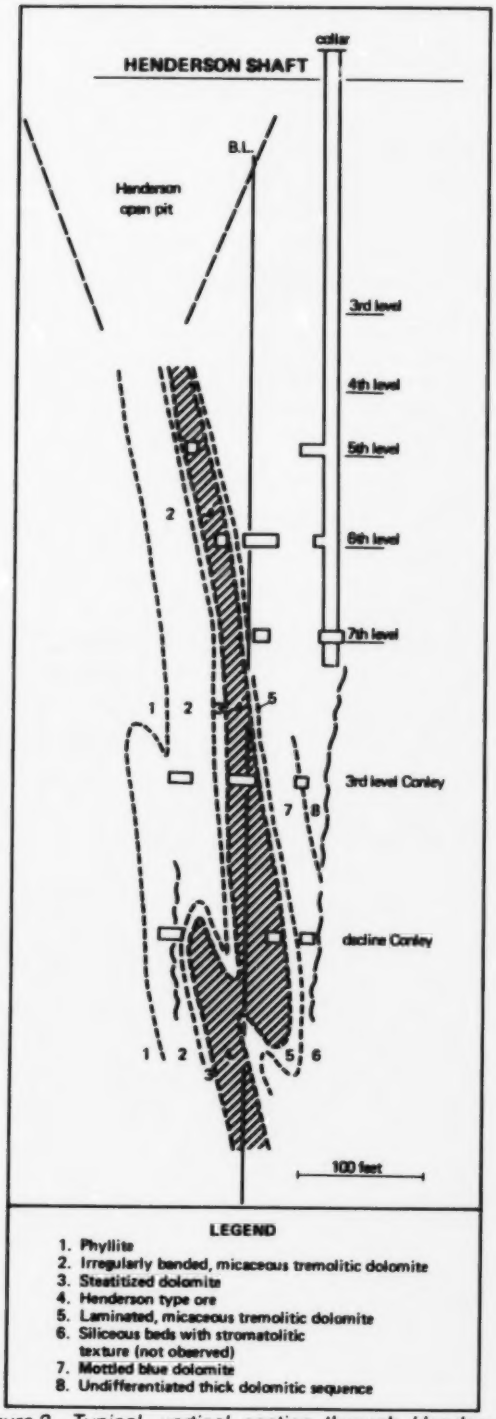

Figure 3—Typical, vertical section through Henderson deposit (after Simandl and Ogden 1982).

quality talc. The Conley orebody is a mixed talc, tremolite, and dolomite rock, containing at least 20% talc. It is mined to make a number of filler and terrazzo chip type products.

The Henderson orebody is a tabular body of variable thickness. Variations in thickness are due mainly to the localization of steeply plunging folds (Figure 3) in which the thickest sequences are to be found. The Henderson orebody is known to be over 250 m long, 7 to 25 m wide, and at least 250 m deep, although the ultimate mineable depth is unknown.

The footwall of the Henderson orebody consists of dark grey to black phyllite overlain by irregularly banded micaceous dolomite containing coarse prismatic tremolite. There has been some steatitization of the dolomite near the contact with the talc orebody. The hanging wall consists of regularly banded micaceous and tremolitic dolomite, containing some siliceous bands. This impure dolomite sequence continues and in it are also found tourmaline-, quartz-, pyrite-, and amphibolite-bearing bands.

The talc ore is of exceptional whiteness and purity. However, near the contact with micaceous dolomite it may contain accessory minerals such as sulphides, amber mica, and prismatic tremolite.

During the summer and autumn of 1981, Canada Talc Industries Limited undertook a program of surface and underground mapping and drilling that resulted in the discovery of the new East orebody, about 200 m southeast of the Conley shaft. Although close to the surface, much of this orebody is covered by a thin capping of Paleozoic limestone that is overlain by glacial till. Stripping of much of the deposit has been completed. There is an initial hard zone approximately 1.1 m thick at the surface, followed by a 10 m zone of discoloured chloritic talc, beneath which is the characteristically snow-white Henderson talc ore.

MINING AND MILLING

Mining of both orebodies is presently from underground, although originally both were open pit operations. The main or production shaft is the Conley, which is 186 m deep. The Henderson shaft is now used only for ventilation, for pumping out mine waste water, and for an emergency exit. At the third level (168 m) a drift connects the Conley shaft with the Henderson orebody. Ramps, declined at 15° from the third level, provide access to both orebodies. The present maximum depth of mining is 250 m. Mining is by induced caving with the ore having been previously undercut and blasted. An air-driven L62 loader removes the ore from draw points positioned every 9 m along strike. Haulage to the ore pocket is by a diesel-powered D5 truck. The ore is hoisted to 2 surface storage bins of 68 tonnes combined capacity by a 0.9 tonne skip.

From the surface storage bins the ore is fed to a 21 by 61 cm jaw crusher where it is crushed to 5 cm, and then con-

veyed to 2 mill feed bins which also have a capacity of 68 tonnes. The crushed material is ground in a 127 cm Raymond Roller mill that produces four minus 44 micron products. All products are bagged in 20 kg bags for shipment by truck.

Canada Talc Industries Limited presently produces Cantal PG, Cantal 325, and Cantal D, all of which are white talc products made from the platey Henderson-type ore. The Company also produces Talfil 325 which is a talcose dolomite produced from Conley ore. These products are all sold to paint, plastics, and rubber manufacturers. Canada Talc Industries Limited also produces a range of white dolomitic chips and sand-sized products that are used for architectural applications.

Present Madoc plant capacity is approximately 20 000 tonnes per year. The Company has recently purchased excellent plant facilities at Marmora, some 18 km west of Madoc, and plans are being completed for new equipment installations at both properties to more than double annual output.

MADOC TO HAVELOCK

0-36 km *Highway 7 between Madoc and Havelock.* Note the Dummer Moraine topography (hummocky glacial drift containing angular Paleozoic limestone fragments) and Precambrian crystalline bedrock. Multiple glaciations over the last 3 million years (Ma) have eroded away the upper 1 to 3 m of the Precambrian Shield rocks leaving a polished, streamlined, rock surface. Local pockets of Paleozoic limestone outliers are present amongst depressions in the Precambrian bedrock.

15 km *Entrance to the former Marmoraton Mining Company Ltd.'s open pit iron mine, 1 km to the south (optional stop).* The mineralization was discovered in 1949 as a result of the first airborne magnetometer survey of this area. Bethlehem Mines Corporation optioned the land and discovered a large magnetite orebody beneath more than 30 m of Paleozoic limestone. Starting in 1955, pelletized magnetite was shipped to Buffalo, and in 1979 the mine closed when the orebody was nearly exhausted. The magnetite orebody was 730 m long and 122 m wide, and averaged 37% iron. Ore minerals were magnetite, pyrite, and pyrrhotite, with garnet and epidote as common accessories.

After the mine closed, Armbro Materials and Construction Limited bought the limestone stripping and the ultramafic waste to use as construction aggregate.

17 km *Crowe River bridge in Town of Marmora.* As we drive uphill note the excellent exposure (20 m) of Black River limestone.

18-20 km *A Paleozoic limestone plain.* Note the roadcuts.

20 km *Diorite and diorite-andesite roadcuts.*

20.8 km *Hastings/Peterborough County boundary.*

21 km *Stony Dummer Moraine.*

31 km *Railroad crossing and road to basalt quarry of 3M Canada Inc. (roofing granules).*

36 km *Havelock (optional stop).* Continue west on Highway 7 for 6 km. Where the highway bends south continue straight along the gravel road for 0.5 km, to where the road cuts through the Norwood Esker. The Norwood Esker forms a prominent ridge.

36-81 km *Havelock to Blue Mountain nepheline syenite mines.* From Highway 7 at Havelock, turn north onto Oak Lake Road. For the first 5 km we travel across the Dummer Moraine. At first the topography is underlain by limestone, then we enter the irregular Precambrian Shield terrain. The Village of Oak Lake is located on a Paleozoic limestone outlier. Note that the roadcuts and farmland at Oak Lake contrast with the surrounding Precambrian Shield rock

81 km *Blue Mountain.* Blue Mountain is a nepheline syenite intrusive which rises 45 to 60 m above the granitic and amphibolitic country rock surrounding it. This nepheline syenite, composed of nepheline, albite and microcline feldspar, and accessory biotite and magnetite, is the only nepheline syenite body in Canada that is being commercially mined.

Stop 2: Nepheline Syenite Mines

We will visit the unique and world-famous nepheline syenite deposit in Methuen Township and the 2 companies operating mines (Photos 3 and 4) and plants (Photos 2 and 5) there.

HISTORY

Commercial exploitation of the nepheline syenite deposits began in 1936, even though they were discovered as early as 1897, and undoubtedly were known much earlier than that. In 1936, Canadian Nepheline Limited began hauling crude ore by wagon and barge to Lakefield, a distance of 40 km, where the ore was processed into glass and ceramic grades in a 45 tonnes per day mill. In 1937 a subsidiary company, American Nepheline Corporation, was formed and a 90 tonnes per day mill was erected at Rochester, New York. Crude ore was barged to Lakefield, transferred to railcars, and then transported to Cobourg where the Canadian National Railway ferry carried it across Lake Ontario to Rochester. In 1946, an initial mill was established at Nephton. In 1956, the completion of a 27 km rail spur from Havelock coincided with the construction of a completely new 550 tonnes per day mill at Nephton which is operated by Indusmin Limited, the present-day successor company. A somewhat smaller plant was built at Blue Mountain by IMC Chemical Group (Canada) Limited (IMC). Both plants have been expanded over the years, and presently the combined annual output is greater than 600 000 tonnes.

GEOLOGY

The geological plan in Figure 4 shows the distribution of the principal rock types in Methuen Township and, in particular, the irregularly shaped intrusive stock of nepheline syenite that is of such commercial importance. The main mass has dimensions of 2 by 4 km while a long sill-like arm about 0.4 km wide by 6 km long extends to the southwest. The nepheline syenite is generally regarded as having intruded and partly replaced para-amphibolite, paragneiss, and marble of the Blue Mountain metasedimentary band.

The nepheline syenite is a uniform, foliated, fine- to medium-grained rock composed essentially of the following: nepheline, 20 to 25%; albite, 48 to 54%; and microcline, 18 to 23%. Characteristic accessory minerals are: magnetite, 0.2 to 0.6%; biotite, 0 to 4%; hastingsite, 0 to 3%; muscovite, 0 to 2%; and aegirine which in total seldom amounts to more than 6%. Minor accessory minerals and secondary hydrothermal and pegmatite minerals are also found. The Blue Mountain intrusive is of Precambrian age. It was emplaced, according to determinations, 1300 Ma ago and was subsequently folded to its present attitudes some 300 million years later during the Grenville Orogeny. Table 1 shows the age relationships of the various rock types in Methuen Township. During our visit to the mines we will see the main plutonic rocks, namely the granite pegmatite, syenite, nepheline syenite, the basic intrusives, and some of the volcanic rocks.

Mineral specimen collectors should be alert to some of the more interesting accessory minerals, e.g. epidote, riebeckite, natrolite, prehnite, analcite, hydronephelite, cancrinite, sodalite, and tourmaline. There are 2 ore types at the mines: the hornblende type and the biotite type.

MINING AND MILLING

Mining of the nepheline syenite orebodies is by open pit. Indusmin Limited operates 2 pits and IMC operates 1. Bench heights at these pits range from 10 to 12 m. Drilling is by self-propelled rotary drills and is followed by blasting using prilled ammonium nitrate explosives. Blasted ore is loaded onto 32 tonne trucks by 4.2 m^3

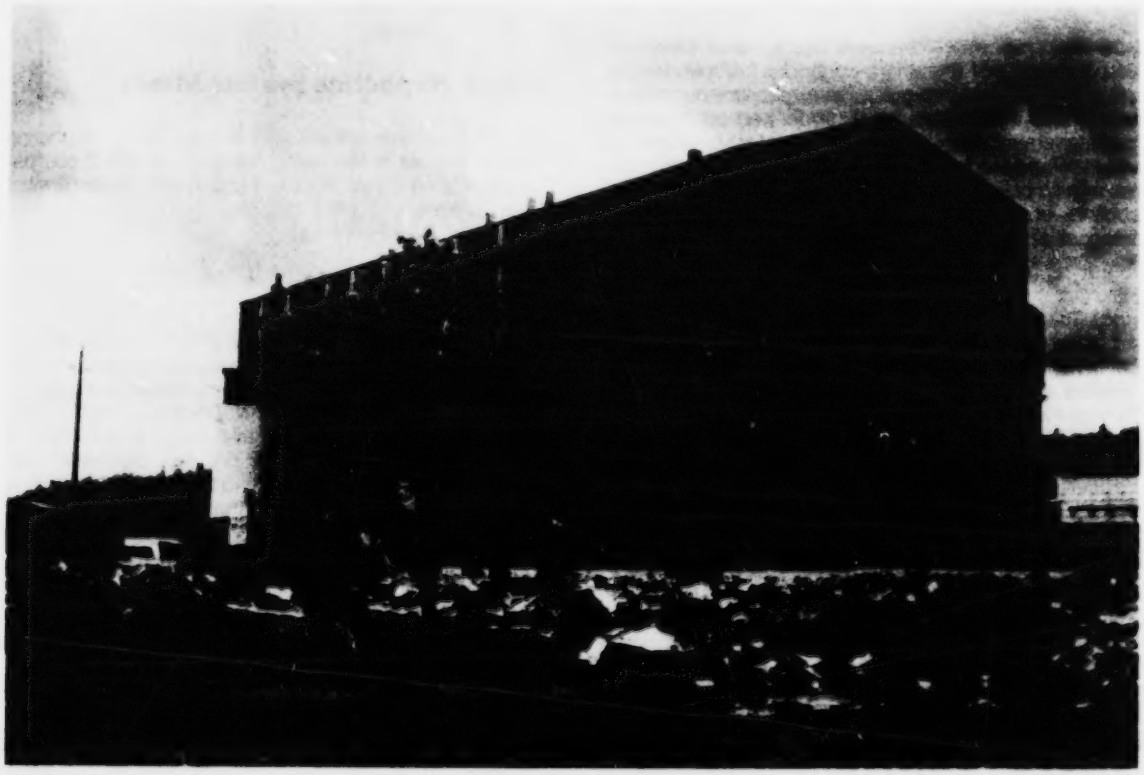

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Photo 2—Nepheline syenite plant, IMC Chemical Group (Canada) Limited, Blue Mountain.

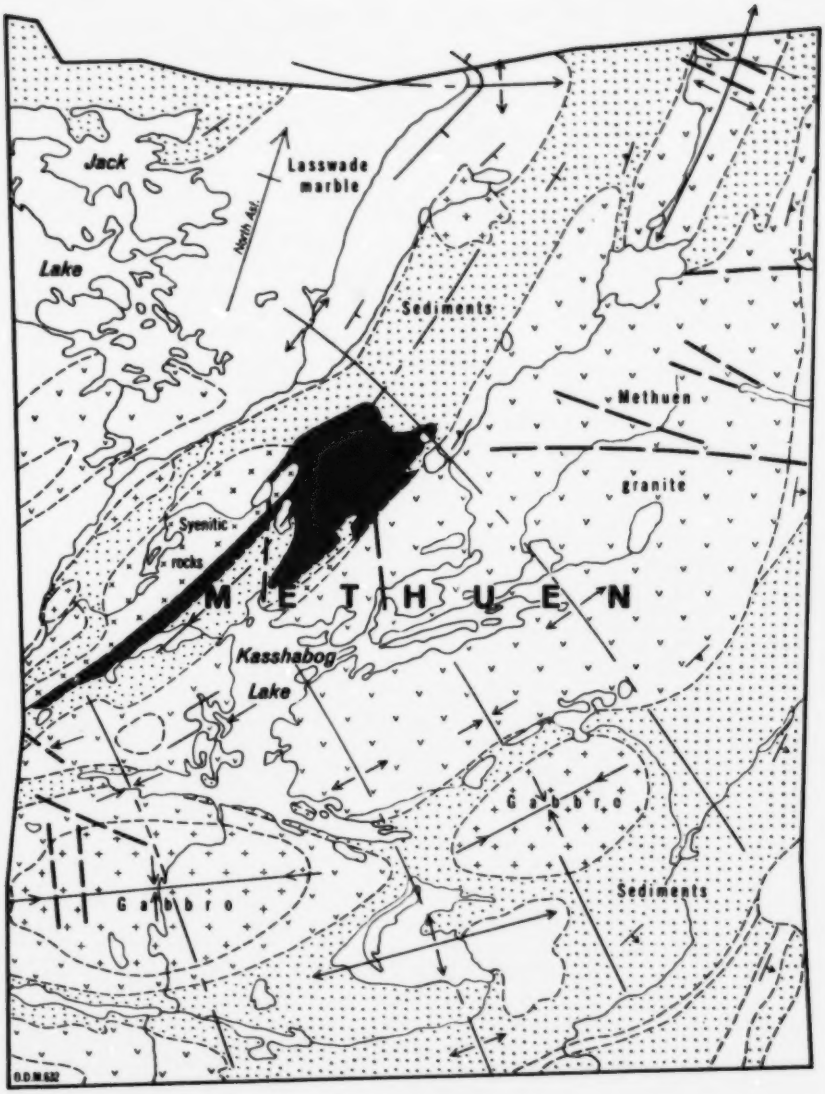

Figure 4—Structural map of Methuen Township (from Hewitt 1961).

TABLE 1 TABLE OF FORMATIONS FOR METHUEN TOWNSHIP (FROM HEWITT 1961)

CENOZOIC		
PLEISTOCENE AND RECENT	Sand, gravel, clay, silt, till.	
	Great Unconformity	
PALEOZOIC		
ORDOVICIAN	Limestone, dolomitic limestone. Red argillaceous limestone and shale. Basal grit and arkose.	
	Great Unconformity	
PRECAMBRIAN		
PLUTONIC ROCKS	Granitic Rocks: granite, granite gneiss, granite pegmatite.	
	Intrusive Contact	
	Syenitic Rocks: syenite, syenite gneiss, hybrid syenite gneiss, syenite pegmatite.	
	Intrusive Contact	
	Nepheline Syenite.	
	Intrusive Contact	
	Basic Intrusives: diorite, gabbro, norite, pyroxenite, amphibolite.	
	Intrusive Contact	
	Southeast Methuen (stratigraphic succession)	Northwest Methuen
SEDIMENTARY AND VOLCANIC ROCKS	Vansickle Formation (approximate thickness, 4,500 feet +): Upper schist. Upper marble. Middle schist. Vansickle conglomerate. Middle marble. Lower schist. Lower marble. Lower conglomerate.	Blue Mountain sedimentary band. Lasswade marble. Apsley formation.
	Oak Lake Formation (approximate thickness, 5,000 feet): Pink arkose, quartzite, amphibolite schist, feldspathic schist, some volcanic amphibolite.	
	Big Island Beds: Interbedded marble and schist.	
	Kosh Lake Beds: Epidotized amphibolite, paragneiss.	approximate thickness, 2,000 feet +.
	Troutling Bay Volcanics.	

front-end loaders and hauled to crushers at the mills. All mining operations are carried out on a 1 shift, 5 days per week basis (Photo 4).

Due to similarities of the ores the general treatment at both properties is somewhat similar. At Nephton (Photo 5), initial size reduction to minus 5 cm is achieved by jaw and cone crushers, after which the ore is stored. Prior to further size reduction, the ore is dried and then crushed with impact and cone crushers, and screened. Plus 30 mesh material is further crushed in rolls crushers, while the minus 30 mesh passes over low intensity magnetic separators to remove the magnetite. Minus 200 mesh fines are then removed by mechanical air classifiers and all the remaining plus 200 mesh feed passes through high intensity dry magnetic separators to remove biotite and any other magnetically susceptible trace minerals. The products, averaging 0.07 to 0.08% Fe_2O_3, are then sized in vibrating screens to produce minus 30, minus 40, and minus 50 mesh products for the glass industry.

Fine grades are produced in quartzite-lined pebble mills that operate in closed circuit with air classifers, to serve the needs of the ceramic, paint, and plastics industries.

At the IMC plant (Photo 2), a rod mill is used instead of rolls crushers to reduce the previously crushed and dried crude ore to achieve mineral liberation. IMC produces a number of grades of nepheline syenite that are also sold to the glass, ceramic, paint, and plastics industries.

Typical product analyses of the Indusmin Limited nepheline syenite are shown in Tables 2 and 3.

END USES

Over 70% of the nepheline syenite produced is destined for glass manufacture, mainly containerware; the product provides important and uniform amounts of alumina, soda, and potash, as well as acting as a flux. Important quantities are also used in flat glass and fiberglass manufacturing.

Research carried out at the Engineering Experimental Station of Ohio State University, in the early years of the Nephton development, provided the basis for the widespread use of nepheline syenite in sanitaryware, dinnerware, wall tile, and various porcelain products.

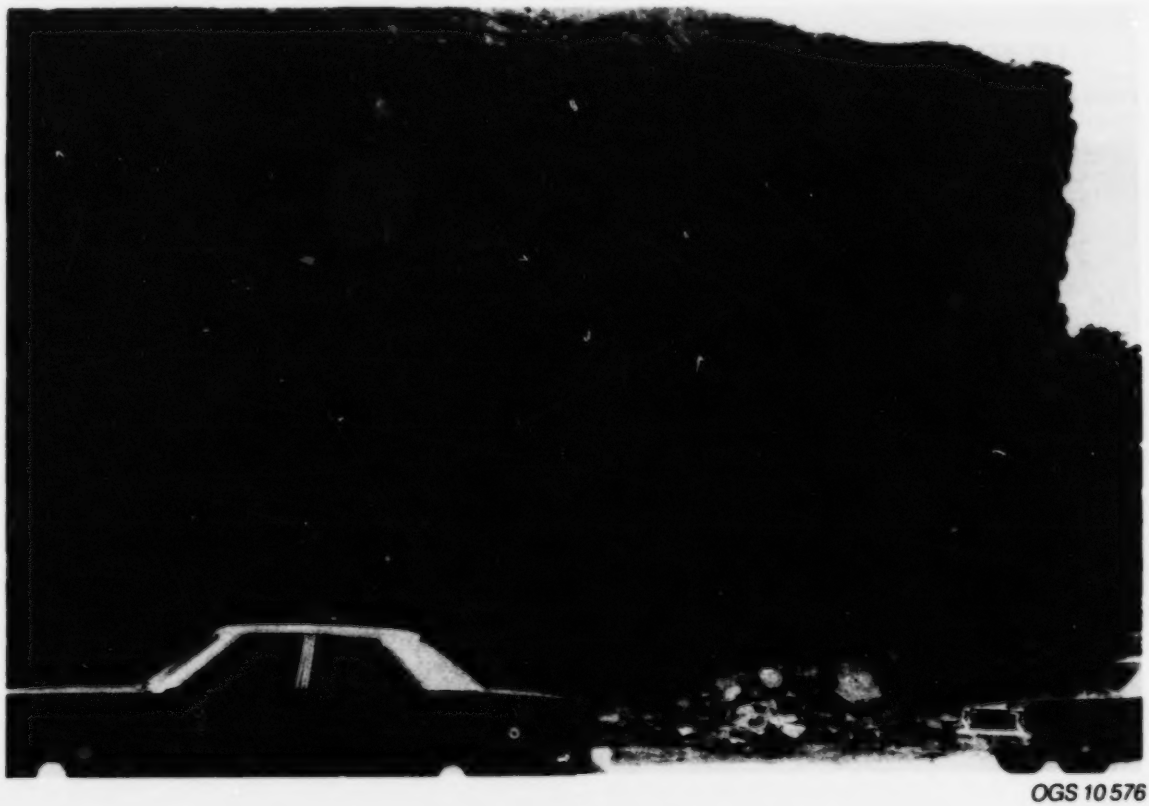

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Photo 3—Nepheline syenite mine, IMC Chemical Group (Canada) Limited, Blue Mountain.

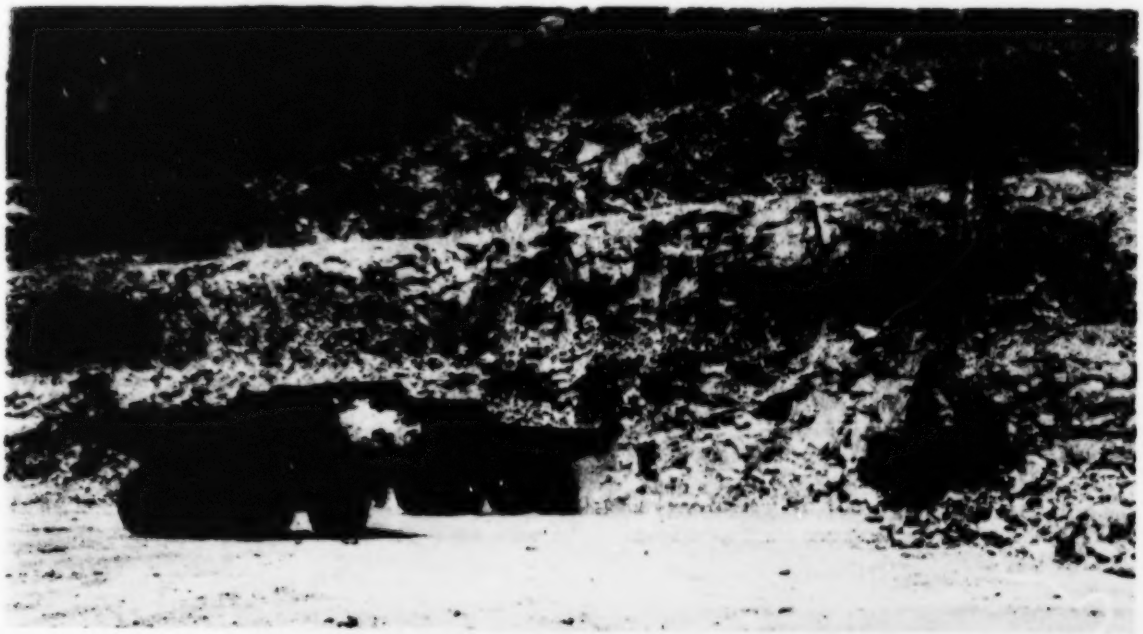

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Photo 4—Nepheline syenite mine, Craig Pit, Indusmin Limited, Nephton.

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Photo 5—Nepheline syenite plant, Indusmin Limited, Nephton.

TABLE 2 | TYPICAL PRODUCT ANALYSIS OF NEPHELINE SYENITE*

	CHEMICAL	%	PHYSICAL PROPERTIES	
Silica	SiO_2	60.1	Specific Gravity	2.61
Alumina	Al_2O_3	23.3	Hardness Mohs Scale	5 to 6
Ferric Oxide	Fe_2O_3	0.07	Refractive Index	1.53
Calcia	CaO	0.7	Pyrometric Cone	6 to 7
Magnesia	MgO	0.1	pH	9.6
Soda	Na_2O	10.1		
Potash	K_2O	4.9		
Loss on Ignition		0.65		
		100.0		

*courtesy of Indusmin Limited

Research by Indusmin Limited at the American Nepheline Corporation laboratory in Columbus, Ohio, in the 1950s and subsequently, has led to the use of nepheline syenite in paints and plastics. In these products, nepheline syenite contributes to the high dry brightness, high bulking value, low vehicle demand, extreme ease of wetting and dispersion, and has a stabilizing pH value. In plastics, nepheline syenite has been used increasingly in rigid, flexible, and plastisol-type polyvinyl chloride, and in epoxy and polyester systems.

Nowhere else in the world has a nepheline syenite deposit been found to match the high quality, uniformity, and consistency of the Blue Mountain and Nephton deposits.

QUALITY ASSURANCE

At the Indusmin Limited and IMC mines and plants, quality assurance is a critically important feature of the production cycle. The control starts right at the definition of an orebody, and follows through the mining and blending stages to achieve the required chemical values for mill feed, and finally includes sample analyses of individual customer shipments.

TRANSPORTATION

Most nepheline syenite shipments are transported by rail. In addition, large amounts are transported in pneumatic- and dump-type truck trailers. Shipments destined for overseas customers move through various ports along the Atlantic coast, the St. Lawrence Piver, and Lake Ontario.

REHABILITATION

Both companies have taken note of public concern for the rehabilitation of waste dumps and worked-out areas. At Indusmin Limited's property, we will see tailings areas on which deciduous trees, grasses, and market garden crops are growing. A trout pond, in the former Cabin Ridge quarry, will also be seen.

BLUE MOUNTAIN TO TORONTO

0-17 km *Blue Mountain to Stony Lake.* This is a typical Shield terrain with variable discontinuous glacial drift overlying Precambrian crystalline bedrock.

17-25 km *Stony Lake to Gilchrist Bay.* We will travel over a limestone plain at Gilchrist Bay which was a major meltwater channel (glacial spillway) connecting Stony Lake to Rice Lake.

25-49 km *Gilchrist Bay to Lakefield.* Here we travel across more of the Dummer Moraine that overlies a limestone plain.

49-64 km *Highway 134 between Lakefield and Highway 7.* Travel through the Peterborough Drumlin Field, a drumlinized till plain. The ice of the Lake Simcoe lobe, which was to the north, advanced in a southwesterly direction. This is indicated by the orientation of the drumlins, which are oval hills of sandy till that formed beneath the moving ice as lodgement till.

64-89 km *Highway 7 to Highway 115.* Peterborough Drumlin Field. The City of Peterborough is located beside the Otonabee River and the Trent Canal, several kilometres south of the Kawartha Lakes. An architectural feature of many buildings in this area is the use of Black River and Trenton limestone. The Otonabee River flows within a sandy glacial outwash channel.

89-106 km *Highway 115, Cavan Township.* Here we cross the Cavan Sand Plain, which was deposited postglacially along the Otonabee River.

106 km *Highway 115, Manvers Township, to Highway 35.* Oak Ridges Interlobate Moraine. We enter the hum-

TABLE 3 INDUSMIN LIMITED NEPHELINE SYENITE BASIC PRODUCT RANGE*

GLASS GRADES	NOMINAL SIZE
−30 mesh low iron	−30 mesh +200 mesh
−40 mesh low iron	−40 mesh +200 mesh
−50 mesh low iron	−50 mesh +200 mesh
−30 mesh high iron	−30 mesh +200 mesh
−40 mesh high iron	−40 mesh +200 mesh
CERAMIC GRADES	
	−200 mesh
	−270 mesh
	−325 mesh
FILLER GRADES	
	−74 micron
	−34 micron
	−20 micron
	−10 micron

*courtesy of Indusmin Limited

mocky topography of this moraine at the Manvers/Cavan Township line. The Oak Ridges Moraine and the Niagara Escarpment are the 2 most distinctive physiographic features in southern Ontario. This moraine has an elevation of over 300 m (1000 feet) a.s.l. and extends eastward from the Niagara Escarpment to the Trent River. It forms the height of land dividing streams of the Lake Ontario basin from those flowing into Georgian Bay and the Trent River. It is more than 150 km long and up to 13 km wide.

The surface is hummocky with a knob and kettle relief typical of an end moraine. The deposits, up to 90 m thick, consist of sand and gravel deposited in a braided river system in front of the northward moving Lake Ontario ice lobe. The ice subsequently advanced over parts of these fluvial sediments, burying them under Halton Till.

The moraine is a major groundwater recharge area. The height of land forms a drainage divide for the many streams which flow across the till plains lying to the north and to the south.

The original hardwood and pine forests were cleared for agricultural land during the early 1800s. Drought conditions in the 1930s caused much of the surficial sandy soils to blow away. Attempts were made to stabilize this sand by reforestation. The present-day pine forest plantations, through which we are travelling, demonstrate the effectiveness of pine plantations in stabilizing these dry sandy soils.

On the more gentle hillsides and outwash aprons the soils are more fertile. These areas are used for pasture or cropland, depending on the slope and texture of the soil. Much of the original agricultural land, however, is increasingly being used for recreation and urban development, particularly near Toronto.

119-134 km *Highway 35 to Highway 401.* Travel down the south slope of the Halton Till Plain. At Orono we enter the lowland of the Iroquois Plain and continue toward Highway 401. We will travel west on Highway 401 for 120 km to Toronto.

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FIELD TRIP B

Industrial Mineral Industries (Aggregates, Stone, and Glass)

by

D.W. Scott and S.E. Yundt

CONTENTS

	Page
GENERAL	23
Bedrock Geology	23
Niagara Escarpment	23
Physiography	24
ROAD LOG	27
Stop 1: Steetley Industries Limited	27
Geology	28
Quarry, Aggregate Plant, and Dried Fines Plant	30
Aggregate and Dried Stone Products	30
Steetley Lime Division: Kiln Operations	31
Kiln Products	31
Stop 2: Standard Aggregates Division of Standard Industries Limited	33
Geology	33
Rehabilitation	33
Stop 3: TCG Materials Limited *by S.B. Lowe*	35
Geology	35
Cornell Pit	35
Main Brantford Pit	35
Chronology: Rehabilitation to Forages and Wheat Crops, Brantford Main Pit	39
Conclusions	39
Stop 4: Nelson Aggregate Co	40
Nelson Quarry	40
Geology	40
Quarry Operation	40
Rehabilitation	40
Trout Pond	40
Pastureland	42
Backsloping, Seeding, and Treeing	42
Stop 5: Consumers Glass Company Limited, Milton Plant	43
REFERENCES AND SELECTED BIBLIOGRAPHY	47

TABLE

1. Clappisons Corner roadcut (after Bolton 1957) 28

FIGURES

1. Paleozoic geology of southern Ontario 24
2. Stratigraphy of the Niagara Escarpment, Niagara Falls to Georgetown (from Telford 1978) 25
3. Route of Field Trip B, showing main physiographic features in the area (after Straw 1968) 26
4. Schematic of the glass bottle manufacturing process 45

PHOTOGRAPHS

1. Aerial view of Steetley Dundas operations with Canada Crushed Stone in foreground 29
2. Steetley quarry face with 6 m of Guelph Formation and 7.5 m of Eramosa Member dolostone overlain by up to 15 m of overburden 30
3. Canada Crushed Stone aggregate plant in background with loading of aggregate for transport to market 30
4. Number 8 mesh fertilizer filler, a Steetley dried fines agricultural product 31
5. Steetley Lime, kiln operation 32
6. Steetley's metallurgical products 32
7. Rehabilitated land owned by Standard Aggregates at Paris 34
8. Standard Aggregates, Paris site, with corn growing on rehabilitated land 34
9. Progressive rehabilitation (Cornell pit, 1982) 36
10. Stripped soil is placed to rehabilitate the pit floor (Cornell pit, 1982) 36
11. Subsoil and topsoil are replaced in separate layers on the pit floor (Cornell pit, 1982) 37
12. Progressive rehabilitation (Brantford main pit, 1979) 37
13. Crop production on rehabilitated land (Brantford main pit, 1980) 38
14. Ploughing-under alfalfa in preparation for a grain crop (Brantford main pit, 1981) 38
15. Quarry face exposing 20 m of Amabel Formation dolostone 41
16. Quarry operation with stripped area and quarry face 41
17. The Nelson quarry trout pond showing the plant and product stockpiles in the background 42
18. Pastureland developed on the slopes of the Nelson quarry 43
19. Consumers Glass Company Limited, Milton plant 44
20. Parison (embryo bottle) being flipped into a finishing mold 46

FIELD TRIP B

Industrial Mineral Industries (Aggregates, Stone, and Glass)

by

D.W. Scott[1] and S.E. Yundt[2]

GENERAL

The field trip is designed to show the glacial and bedrock geology of part of south-central Ontario, to cover associated industrial mineral resources and industries dependent on these geological deposits, and to indicate how extracted lands are rehabilitated. Stops will include crushed and metallurgical stone operations, sand and gravel operations, rehabilitation of extracted lands, and a glass-container plant.

The field trip area is a major source of supply for the aggregate demand of the Toronto region. Twenty-four million tonnes of aggregate are produced annually in the field trip area, 12 million tonnes from the bedrock formations and 12 million tonnes from the unconsolidated sand and gravel deposits. In addition, 0.8 million tonnes of shale are extracted from the Georgian Bay Formation and Queenston Formation of Ordovician age for the manufacture of brick, drainage tile, and other ceramic products.

Bedrock Geology

The field trip traverses areas underlain by Ordovician shales and Silurian carbonate and clastic rocks. The strata dip southwesterly into the Michigan basin with the contact between the Ordovician and Silurian rocks occurring at the Niagara Escarpment, situated approximately 60 km west of Toronto (Figure 1).

The Ordovician shales of the Georgian Bay and Queenston Formations are used in the manufacture of brick and tile, and for lightweight aggregate. The Silurian age carbonates of the Amabel Formation are an excellent source of high quality aggregate for use in concrete and asphalt pavement. The Guelph Formation of Silurian age, located to the west of the Niagara Escarpment, is a source of high purity dolostone used in the manufacture of metallurgical stone and Dolime.

Niagara Escarpment

The Niagara Escarpment is a prominent geological and topographical feature in Ontario. This feature extends in a generally northwest direction from Queenston on the Niagara River to Tobermory at the tip of the Bruce Peninsula. At Tobermory the escarpment disappears beneath the waters of Lake Huron and reappears on Manitoulin Island, and extends westward into the State of Michigan. East of Queenston, it extends into the State of New York.

Since the Niagara Escarpment is a distinct feature rising in height to over 90 m and is located near highly populated areas in southern Ontario, it is an important landform in regard to scenic value and recreational use. The escarpment is also an attractive area for the development of the extractive industry as well as permanent and seasonal residences. Because of the social and economic pressures for development on the escarpment, it became important to relieve some of the pressures of competing land uses. This resulted in the "Niagara Escarpment Planning and Development Act, 1973" which stipulated that a plan for the Niagara Escarpment be prepared. Section 2 of the Act states that the plan will "provide for the maintenance of the Niagara Escarpment . . . substantially as a continuous natural environment." The Niagara Escarpment Commission was thus created in 1973 by the Ontario Government to maintain the natural environment and meet the planning needs of the escarpment.

The rocks which form the Niagara Escarpment contain an interesting geological history of Upper Ordovician to Middle Silurian time. During this period of time, which dates back some 400 to 500 million years (Ma), a succession of shales, sandstones, limestones, and dolostones were deposited. The succession of rock strata exposed along the Niagara Escarpment between Niagara Falls and Georgetown is shown in Figure 2. The oldest rocks exposed in the escarpment are the red shales of the Queenston For-

[1]Supervisor, Aggregate Assessment Office, Engineering and Terrain Geology Section, Ontario Geological Survey, Ontario Ministry of Natural Resources, Toronto.

[2]Supervisor, Industrial Minerals Section, Mineral Resources Branch, Ontario Ministry of Natural Resources, Toronto.

mation which were deposited on a deltaic piedmont plain during the Ordovician Period. The shales form the base of the present-day escarpment and are an important raw material for the clay products industry.

The Silurian age Whirlpool Formation rests sharply on the Queenston strata. It consists of tan or grey quartz sandstone which has been quarried for use as building stone, silica grit, and ganister. Overlying the Whirlpool Formation in the Niagara Peninsula are the Cabot Head, Grimsby, and Thorold Formations. The source area for the sediments which formed these shales and sandstones was probably the Appalachian Mountains, which were being uplifted to the southeast. The sandstones and shales of the Grimsby and Thorold Formations have pinched out to the north of Georgetown, indicating a southerly source for the material. A southerly source of detritus for these formations is also indicated by the presence of the Manitoulin dolostone in the more northern areas: the clastic (clay, silt, and sand) influence decreased in this direction allowing for the deposition of carbonate (limestone and dolostone).

Following the deposition of the Cabot Head, Grimsby, and Thorold strata, the clastic influence from the source area decreased and during the middle part of the Silurian Period carbonate deposition became prevalent. An exception, however, is the shales of the Rochester Formation, deposited in the Niagara and Hamilton areas, which indicate a reactivation of the source area. Of the carbonates deposited during the Middle Silurian, the resistant dolostones of the Amabel and Lockport Formations are the most important in regard to industrial mineral applications. These formations are suited for the production of crushed stone and, because they form the cap rock of the escarpment, are readily accessible for extractive development.

The Niagara Escarpment formed over a long time span, beginning at the end of the Devonian Period when millions of years of erosion commenced. The erosional forces were similar to those currently active, with running water playing the major role. This erosion is still occurring today as witnessed at Niagara Falls. Over this long period of erosion the less resistant rocks were stripped away, leaving the resistant Silurian age Lockport-Amabel Formation as the cap rock of the escarpment. The underlying softer shales, sandstones, and dolostones eroded more quickly, thus undercutting the cap rock. This undercutting has resulted in the present topographic feature which has since been modified by glacial activity.

Physiography

The major physiographic features in southwestern Ontario (Figure 3) are the Niagara Escarpment and several major end moraines. The outwash deposits associated with the end moraines are of considerable extent in the

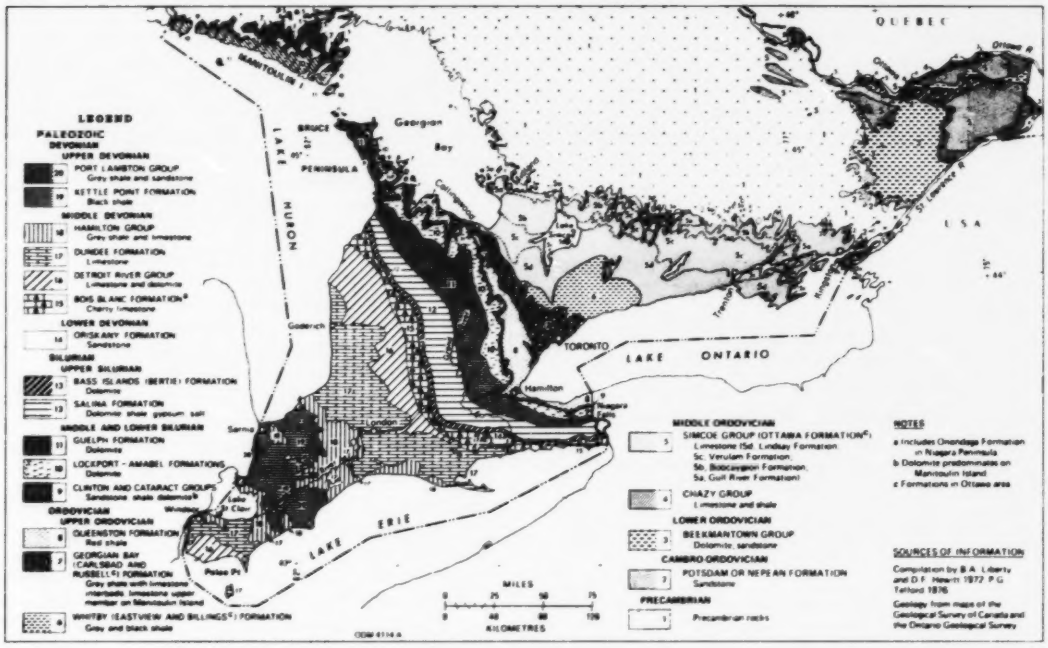


Figure 1—Paleozoic geology of southern Ontario.

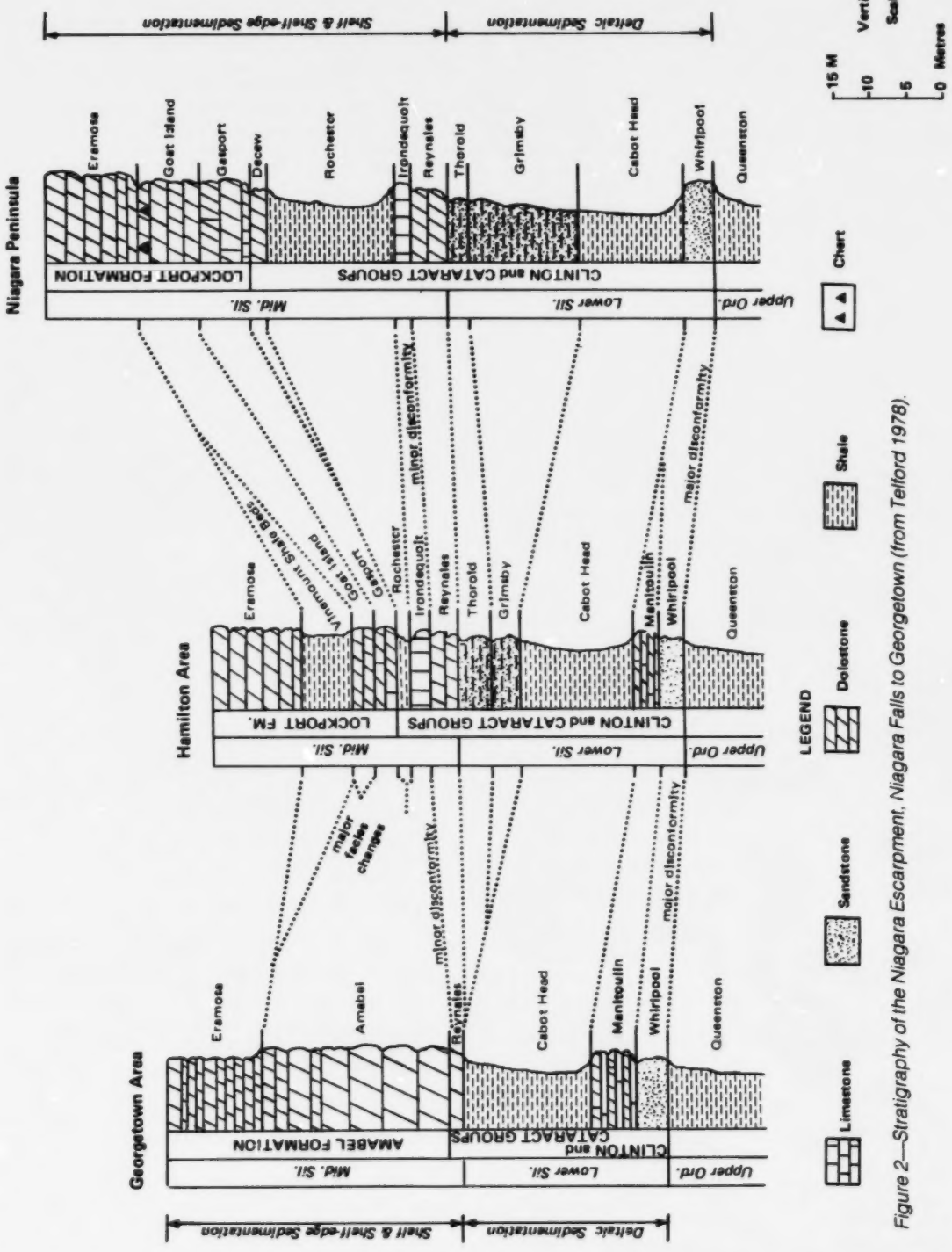


Figure 2—Stratigraphy of the Niagara Escarpment, Niagara Falls to Georgetown (from Telford 1978).

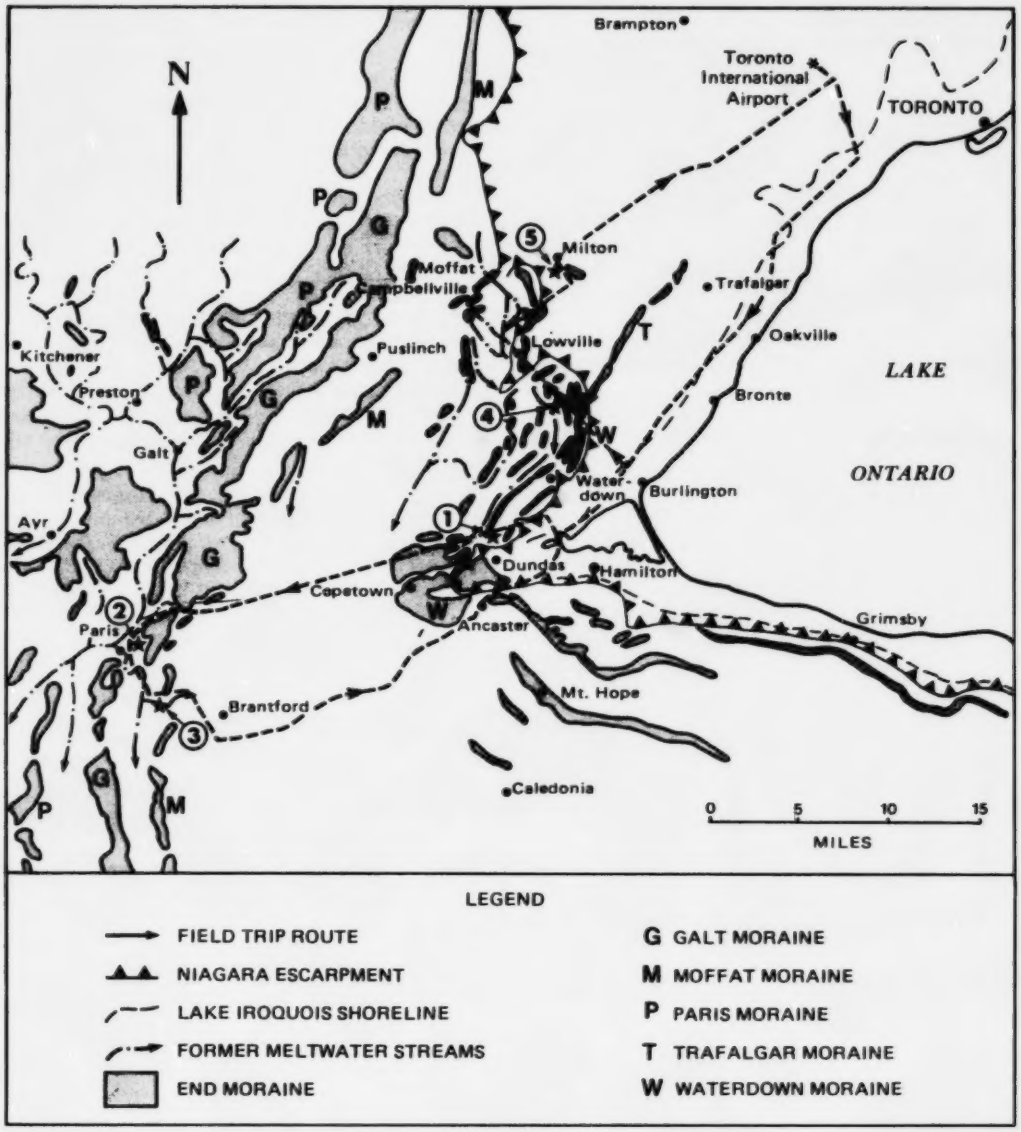


Figure 3—Route of Field Trip B, showing main physiographic features in the area (after Straw 1968). The numbers correspond to field trip stops in the text.

Guelph, Cambridge, Paris, and Brantford areas. The last glacial ice advances, approximately 14 000 years Before Present (B.P.), in the area covered by this field trip were largely from the Lake Ontario basin. The major moraines in the area, deposited by the Lake Ontario lobe, are the Paris, Galt, Moffat, Trafalgar, and Waterdown Moraines, with numerous associated outwash deposits (especially with the Paris and Galt Moraines). The Paris Moraine is the westernmost of the moraines located in the field trip area. It is a belt of hummocky till and sand with pitted outwash and occasional kames. The moraine consists of sandy Wentworth Till. The most prominent moraine in the area is the Galt Moraine, situated several kilometres to the east of the Paris Moraine. The Galt Moraine is also composed of Wentworth Till, forming a belt of rough, hummocky topography.

Two till plains associated with the glacial advances occur in the field trip area. Located farther to the west is the older, flat, Wentworth Till plain; it has a thin sheet of sandy till overlying older deposits often consisting of outwash materials.

The Halton Till plain, situated to the east of the Niagara Escarpment, contains a younger, silty till. The topography in this area is gently undulating to rolling with a thickness of up to 12 m of till resting on the underlying bedrock shales.

During the melting of the glacier ice, glacial Lake Iroquois occupied the Lake Ontario basin. This lake stood approximately 35 m higher than Lake Ontario in the Hamilton area and existed about 12 000 years B.P. At several points along the field trip route the Lake Iroquois shoreline will be crossed.

The major bedrock valley in the Hamilton area has been modified by glacial activity. The preglacial Dundas Valley was widened by glacial erosion and was modified by the deposition of glacial till and glacial lake deposits. A deep, buried gorge exists below the present valley. In the area of the Burlington bar the valley's base is 63 m below sea level or 137 m below present lake levels. This valley has been traced to the west and connects with the Grand River Valley.

ROAD LOG

From the hotel on Airport Road proceed south along Highway 427. At the Dundas Street interchange Highway 427 passes over the raised shorebluff of glacial Lake Iroquois. The shorebluff is presently obscured by urban development. At the interchange with the Queen Elizabeth Way (QEW) proceed west along a plain formed by glacial Lake Iroquois. The Lake Iroquois Plain in this area is essentially a level, sandy plain. In places the plain is composed of washed till. The plain is bounded to the north by the Lake Iroquois shorebluff. Proceed through Mississauga; at Southdown Road (Exit 126 at kilometre 24) climb up the Lake Iroquois shorebluff onto a level promontory underlain by Queenston Formation red shale. A gravel pit formerly worked in the beach deposit at this point is now occupied by a landfill site. At the Highway 403 interchange (Exit 123 at kilometre 29) descend from the promontory back across the Iroquois shorebluff onto the Iroquois Plain. The plain in this area consists of bevelled Queenston shale. Continue along QEW to Highway 403 near Hamilton. Proceeding west on Highway 403 there is a sand plain underlain by the Queenston Formation. At kilometre 53 is the Aldershot Bar with several depleted pits in it; located at kilometre 56 is the plant and quarry of Halton Ceramics Limited, a producer of tile, some brick, and flowerpots, etc. Turn north onto Highway 6 and begin ascending the Niagara Escarpment. The Silurian bedrock is exposed in the Highway 6 roadcut (kilometre 60), and illustrated in Table 1. After ascending the escarpment enter into the Waterdown Moraines (Halton Till) area. At Highway 5 proceed west and travel across these moraines to Stop 1, Canada Crushed Stone (Division of Steetley Industries Limited), at kilometre 67.

Stop 1: Steetley Industries Limited

Canada Crushed Stone, Division of Steetley Industries Limited, operates one of the largest stone quarries in Canada in terms of its size and product range (Photo 1). Serving the construction, steel, glass, agriculture, and filler markets with a wide range of products, the Division processes approximately 2.5 to 3 million tonnes annually.

Canada Crushed Stone is a division of the Minerals Group of Steetley Industries Limited (North America), which is part of the worldwide Steetley PLC manufacturing and trading organization. The parent company, which originated in England in 1885, is involved in the production of a wide range of construction materials, refractories, and building products, as well as the distribution of industrial, electrical, and safety supplies. Steetley is active around the world, including Great Britain, the United States, Australia, New Zealand, France, Italy, Spain, West Germany, and Saudi Arabia.

The Minerals Group of Steetley Industries Limited (North America) has 6 divisions and 2 subsidiaries. The subsidiaries are: Steetley Talc Limited at Timmins, Ontario; and Steetley Resources Incorporated near Toledo, Ohio, which includes the Ohio Lime Company, a major kiln and crushed stone operation, the nearby Gibsonburg dolomitic lime plant, and the recently acquired Millersville dolomitic lime plant. Total dolomitic lime capacity is over 500 000 tonnes.

Five of the six divisions are located at the Dundas site which includes Canada Crushed Stone, Steetley Lime, Steetley Landfill, Steetley Transport, and Steetley Steel Slag. The sixth division, Queenston Quarries, is located near Niagara Falls.

The Dundas quarry of Canada Crushed Stone is located northwest of the City of Hamilton and north of the Town of Dundas. The plant and quarry workings are situated in lots 10 and 11, concession II; lots 9 to 12, concession

TABLE 1 | **CLAPPISONS CORNERS ROADCUT (AFTER BOLTON) 1957, p.93)**

FORMATION OR MEMBER	DESCRIPTION	THICKNESS FEET	(METRES)
Lockport Formation Goat Island Member (Ancaster chert beds)	Dolomite; buff granular to dense; abundant grey, dense to white, fossiliferous chert nodules and lenses.	9	(2.7)
Gasport Member	Limestone; dolomitic, dark grey to whitish grey, crystalline; crinoidal, fossiliferous.	10	(3.0)
Rochester Foundation	Limestone; argillaceous, dark grey, dense to crystalline; dense, grey dolomite (?) pebbles; basal 1 foot sandy, calcareous shale with argillaceous limestone interbeds; upper contact undulating.	2.4	(0.7)
Irondequoit Formation	Limestone; blue-grey to dark grey, crystalline; vugs with calcite and gypsum; upper 8 inches darker grey with argillaceous dolomite pebbles; uppermost beds argillaceous transition phase as at Hamilton; minor basal conglomerate above undulating lower contact; fossilferous.	6.8	(2.1)
Reynales Formation	Limestone; dolomitic, grey, dense; grey shale partings.	9	(2.7)
Thorold Formation	Shale; greenish grey, interbedded with sandstone, grey, fine-grained.	13.5	(4.1)
Grimsby Formation	Sandstone; red, fine-grained, interbedded with shale, red and green.	Visible as a small, slumped exposure on south side of the highway.	

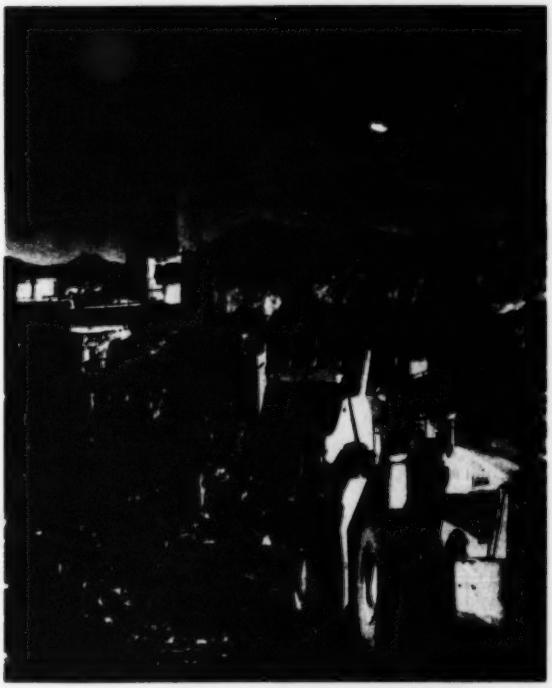
III; and lots 7 to 10, concession IV, Township of Flamborough. This area lies on both sides of Highway 5. Extraction has ceased in the quarry to the south of Highway 5; it is now the site of a modern aggregate plant, stone pulverizing plant, portable crushing plant, and kilns of Steetley Lime. Included on this site, but not operated by Steetley, is an asphalt plant and a ready-mix concrete plant. To the north of Highway 5, stone is extracted for aggregate from the lower bench. Excessive overburden (up to 15 m) on the upper bench necessitated the opening of a new quarry on the next concession north of the existing quarry.

GEOLOGY

The quarry north of Highway 5, in lots 9 to 12, concession III, has 2 benches with a total rock thickness of 18 to 21 m, overlain by up to 15 m of silty Halton Till and lacustrine fine sands deposited in glacial Lake Whittlesey. The upper lift, of approximately 14 to 15 m in height, has produced stone used for aggregate, metallurgical stone, and dolomitic lime. This face is composed of 6 to 7 m of Guelph Formation rock, which is a light grey, aphanitic, medium-bedded dolostone, underlain by 6 to 8 m of dolostone of the upper part of the Eramosa Member of the Lockport Formation (Photo 2). This rock is a medium brown to light brown, aphanitic, medium- to thick-bedded dolostone with some black shaly partings in the lower part of the section. This unit appears to be a transitional unit between the Guelph Formation and the more characteristic rock of the Eramosa Member. This upper lift of 14 to 15 m has been reported to have less than 0.5% silica and less than 0.5% alumina plus iron oxide, and is a high purity dolostone (Hewitt 1960).

OGS 10 579

Photo 1— Aerial view of Steetley Dundas operations with Canada Crushed Stone in foreground and Steetley Lime in the left background. Located in the site from right to left is the scale house and ready mix concrete plant, asphalt plant, wash plant, magnesium lime plant, aggregate plant, dried fines plant, and kiln operation.



OGS 10 580

Photo 2—Steetley quarry face with 6 m of Guelph Formation and 7.5 m of Eramosa Member dolostone overlain by up to 15 m of overburden. Drilling is by an Ingersol Rand Model DM 45 downhole drill. Loading of rock is by a 13.1 m³ Letourneau (Marathon) diesel electric loader into 74 tonne haul trucks.

The 6 m high lower lift is part of the Eramosa Member of the Lockport Formation. Characteristic of this Member is the medium to dark brown or black, very finely crystalline, thin-bedded dolostone. Laminations and petroliferous bands are common. Vugs occur in the lower part of the face and may be filled with gypsum, calcite, or chert. There is a higher concentration of silica and alumina in the Eramosa Member rock of this lift. This is confirmed visually by the increase in chert and shaly material.

QUARRY, AGGREGATE PLANT, AND DRIED FINES PLANT

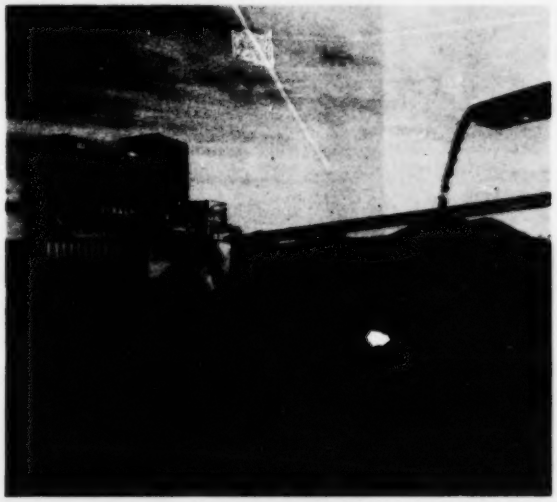
The dolostone quarried at Steetley is used for a variety of purposes, ranging from armour stone to dolomitic lime. There are extensive reserves (648 ha) consisting of 100 million tonnes of metallurgical stone and 120 million tonnes of commercial aggregate stone. The newly opened quarry is located on these reserves.

Stone is quarried by drilling and blasting with a combination of ammonium nitrate, fuel oil, and aluminized slurry. The blast rubble is hauled in 68 tonne haulers to the 107 cm primary crusher with two 51 cm gyratories, capable of producing 1000 tonnes per hour, of minus 15 cm stone. Following primary reduction, the stone is crushed to less than 63 mm with 107 cm cage mills, two 1.2 m SH (short head) cone crushers, and one 1.7 m standard cone crusher. Screening is by double-deck F 800 Tyler Screens as follows: two 1.8 by 4.3 m screens with 63.0 mm and 37.5 mm openings; followed by two 2.1 by 4.9 m screens with 22.4 mm openings and 19 mm openings; followed by two 2 by 6 m screens with 13 mm and 16 mm openings; followed by two 1.8 by 4.9 m screens with 5 mm and 3 mm openings. The secondary plant is designed to produce 1600 tonnes per hour of a full range of stone sizes. The products are conveyed to surge piles or bins. Blending of sizes can occur to meet virtually any specification (Photo 3).

AGGREGATE AND DRIED STONE PRODUCTS

The Company offers more than 120 blends of products from various combinations of the 46 stockpiles. Exclusive of blended materials numerous products are produced, including the following from largest to smallest:

- armour stone, in 3 to 5 tonne, 5 to 6 tonne, and 6 to 9 tonne sizes, which is used for shore protection and has been shipped as far as Tobermory on Lake Huron



OGS 10 581

Photo 3—Canada Crushed Stone aggregate plant in background with loading of aggregate for transport to market. In foreground is oscillating conveyor system that evenly distributes the particles of concrete aggregate in stockpile.

- rip rap material produced in the 10 to 30 cm size used in shore protection, and in the past 15 years over 3.6 million tonnes from this site has been used in the Hamilton Harbour area
- gabion stone in the 10 to 20 cm size is also produced for shore protection
- metallurgical grade dolomite (5.1 by 2.5 cm) is used for blast furnace flux, as well as kiln feed to produce a range of dolomitic lime products for use in the steel and glass industries
- concrete and asphalt aggregate is another major product, in sizes of minus 19 mm concrete aggregate, H.L. (hot laid) 6 stone, H.L. 5 wash stone, H.L. 3 (minus 13.2 mm) stone, 6.4 mm chip for cold mix and surface treating, and manufactured sand

Not far away from the large aggregate plant is the dried fines pulverizing plant. Screenings from the aggregate plant are processed to produce products destined for the agricultural, glass, and filler markets

- fertilizer grits, which is minus 3.4 mm mesh and retained on 1.6 mm mesh as a fertilizer filler (Photo 4)
- a fine sand which is minus 1.6 mm mesh plus 75 μm mesh is used in the glass industry and for cow bedding
- agricultural limestone (agricultural index 75)
- fillers (minus 75 μm mesh) for roofing shingles and sound deadeners

OGS 10 582

Photo 4— Number 8 mesh fertilizer filler, a Steetley dried fines agricultural product.

In addition to the crushed and pulverized dolomite products there are several steel slag products produced at this site and the nearby Old Brow Quarry site located a few kilometres away. The steel slag is processed as a skid resistant aggregate replacing trap rock in many road surface applications. They make 3 products: H.L. 1 (replacing trap rock); dense friction coarse (D.F.C.) which has coarse as well as fine material in it, thereby not requiring sand for making asphalt pavements; and open friction coarse (O.F.C.) which is an open grain material of minus 9.5 mm with 2% passing the 75 μm mesh with the main grain size concentration being 7.9 mm material, and is used in asphaltic concrete which creates a pavement that produces a lower decibel level and reduces hydroplaning on wet pavement.

STEETLEY LIME DIVISION: KILN OPERATIONS

Steetley Lime is located at the eastern end of the processing plant area in Lot 11, Concession II, Township of Flamborough. There are 3 rotary kilns (Photo 5) producing dolomitic lime and dead burned dolomite at this site with the following specifications:

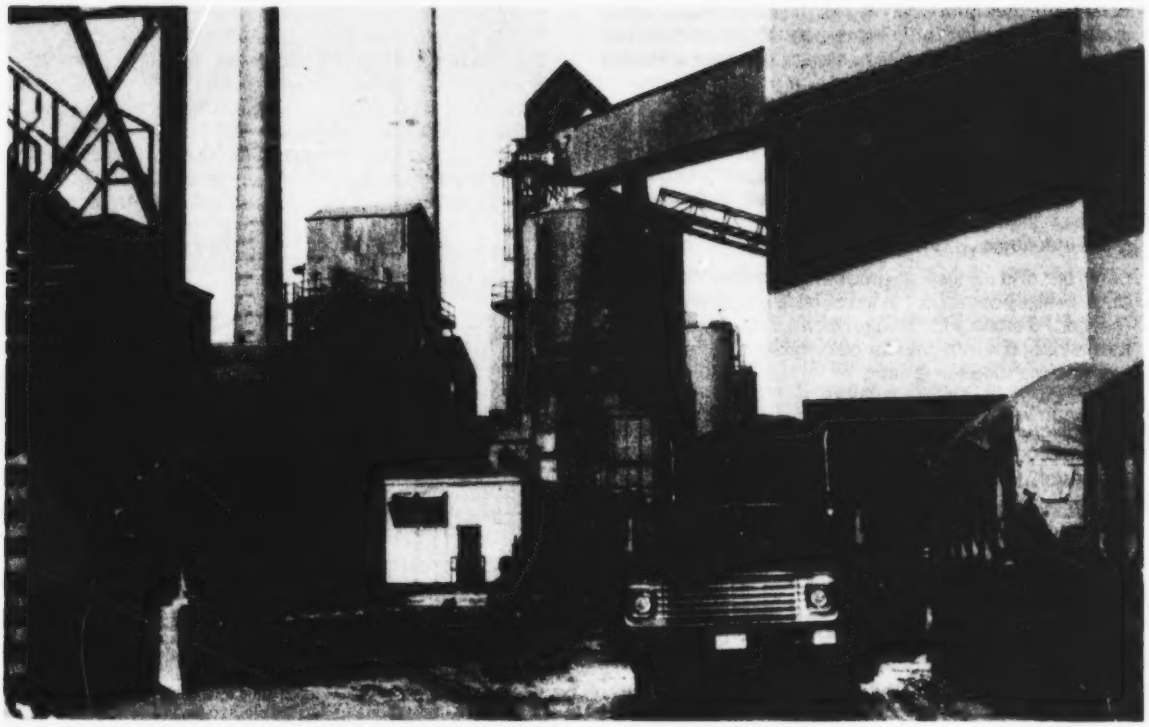
1. Kiln number 1 is a 106.4 m long F.L. Smidth kiln with a diameter of 2.7 m at the feed end and 3 m at the firing end, with the clinker discharging to a Niems cooler. The kiln is fired by solid or oil fuels only.
2. Kiln number 2 is a 91.4 m long F.L. Smidth kiln with 3 m diameter for the full length, with clinker discharging to a Fuller grate cooler. It is fired by solid or oil fuel, and can burn some gas.
3. Kiln number 3 is a 117.3 m long Fuller kiln with a 3.5 m diameter for the full length, with the clinker discharging to a Niems cooler. This kiln is fired by solid, oil, or gas fuels.

The total production capacity from the 3 kilns is 400 000 tonnes per year requiring approximately twice as much feed. Two sizes of stone (minus 63 mm plus 37.5 mm, and minus 37.5 mm plus 19 mm) are used as feed. Following burning the clinker may be crushed and/or screened depending on the customer specifications. There is approximately 3000 tonnes of product storage.

KILN PRODUCTS

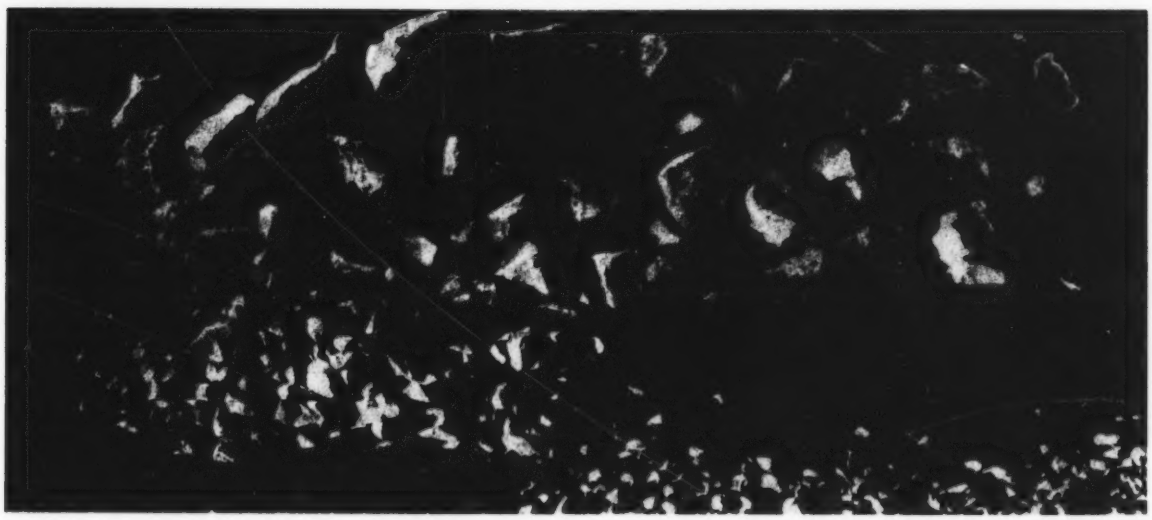
The larger feed material is used to make Dolime (soft burned dolomite) at a kiln temperature of 1538°C. Dolime is used by the steel companies for slag conditioning in Basic Oxygen Furnaces (Photo 6). When in contact with molten steel the Dolime goes into solution, and ties up the silica which would destroy the furnace lining and the sulphur which if not removed would result in a low quality steel.

The smaller size feed material is used to manufacture dead burned dolomite called Dolomax at a kiln temperature of 1649° to 1760°C. Dolomax is coated with iron ox-



OGS 10 583

Photo 5— Steetley Lime, kiln operation, number 3 kiln to the left with product storage and loading facilities in the background and to the right.



OGS 10 584

Photo 6— Steetley's range of metallurgical products for the steel industry including Blast Furnace stone (5 by 2.5 cm), slag conditioning products for the Basic Oxygen Furnace (dolomitic lime and Ferrodolime), and fettling products for the Open Hearth and Electric Furnace (Dolomax 0.95 and 0.48 cm).

ide (mill scale) and is used to fettle Open Hearths and Electric Furnaces.

Dolopel is a double burned, special hard, high-purity dolomite grain for the production of pitch bonded and fired refractory bricks. Another special product, Dolomax "G", is used as a refractory raw material in gun mixes to protect the linings of steelmaking vessels.

A new product called Ferrodolime is a soft burned dolime coated with iron oxide in the kiln and is used as a slag conditioner in the Basic Oxygen Furnaces and Electric Furnaces. The iron oxide coating creates a dust-free product that goes into solution more readily due to its smaller particle size.

From Steetley Industries' quarry, continue west on Highway 5 to St. George. Between Steetley Industries and St. George is the Norfolk Sand Plain: a level plain consisting predominantly of sand with some silt and clay deposited in glacial Lakes Whittlesey and Warren, and underlain by Wentworth Till. West of St. George is the Galt Moraine which is composed of Wentworth Till. From the intersection of Highways 5 and 24 proceed west on Brant County Road 35 which passes over the Galt Moraine. At kilometre 96 is the former site of an early marl cement plant, where marl was dredged from Blue Lake and processed into portland cement, by the Ontario Portland Cement Company between 1904 and 1917. At its peak this operation produced 500 barrels per day. Farther west is the Grand River outwash plain. At the intersection of Brant County Roads 35 and 14 proceed southwest on Brant County Road 14 to the Green Lane in Paris. Continuing along Brant County Road 14, the Grand River is located on the right. Stop 2 (Standard Industries Limited) is located at kilometre 102.

Stop 2: Standard Aggregates Division of Standard Industries Limited

Standard Aggregates operates in 13 locations throughout southern Ontario and is one of Canada's major aggregate producers. It produces 4 to 5 million tonnes annually, with production of sand, gravel, and limestone. They rehabilitate an average of 40 ha per year and presently have approximately 405 ha of reclaimed land to their credit.

The Standard Aggregates East Paris pit has been operating since the late 1920s and considerable amounts of aggregate have been extracted during this time. There are presently 2 areas under license, occupying 78 ha, both located to the east of the Green Lane. The area to the west of the Green Lane was worked out and rehabilitated prior to 1971 when "The Pits and Quarries Control Act" was passed.

GEOLOGY

The gravel deposit is part of the Grand River spillway, which is thought to have been deposited during the Port Huron Stadial at about 13 000 years B.P. The deposition of this gravel occurred at the same time as the Wentworth Till and Paris Moraine were deposited, as well as later during the formation of the Galt Moraine.

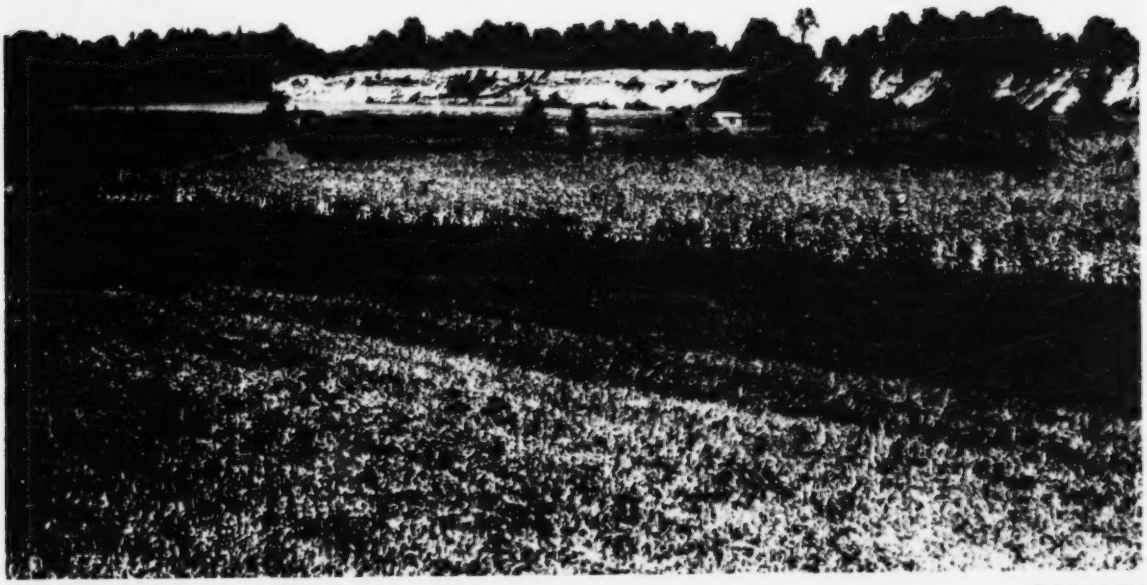
Generally, the spillway deposit is from 9 to 18 m thick, thinning away from the Grand River. Faces in this pit are approximately 14 m high. The gravel content (material greater than the No. 4 mesh screen) of the pit is approximately 60 to 85%. The material is predominantly uniform, horizontally stratified, coarse gravel, with occasional seams of fine sand and silt. Cowan (1972) reports that 70% of the pebbles and cobbles are greater than 2.5 cm in diameter and that 15% are greater than 10 cm. The major lithology present in the gravel is dolostone with minor amounts of limestone, siltstone, and Precambrian rocks, and rare occurrences of chert. This deposit is a good crushing source and the material is acceptable for a wide range of products.

The plant at this site has the capability of producing 27 products, with usually 5 or 6 sand and 7 stone products being produced at any one time; consequently by blending they can supply a larger number of products than most other aggregate operations. Further detail on the plant specifications is found in Hewitt and Cowan (1968).

REHABILITATION

Reforestation, of pit floor and graded slopes, using 9 species (predominantly white spruce, red pine, and European larch) has taken place since 1967. In the period 1967 to 1974, about 30 000 trees were planted, with a high rate of survival. Other parts of the property have been returned to an agricultural use (Photo 7). Local farmers have been engaged in planting and harvesting corn (Photo 8), achieving yields of 5360 kg/ha (normal yield is approximately 6000 kg/ha). A local farmer purchased 8 ha of rehabilitated land from Standard Aggregates for use as crop land. On completion of extraction and rehabilitation, the property will be able to accommodate agriculture, conservation/recreation, or industrial/residential after-uses.

From Standard Aggregates proceed south along Highway 2 and Brant County Road 27. Cross over the Galt Moraine again and descend onto the Grand River outwash plain. Continue to Stop 3, TCG Materials Limited, at kilometre 107.



OGS 10 585

Photo 7— Evidence of corn growing in the early stages and the thousands of trees planted between 1967 to 1974 on rehabilitated land owned by Standard Aggregates at Paris. In the background is the open face for future extraction.

OGS 10 586

Photo 8— Standard Aggregates, Paris site, with corn growing on rehabilitated land. The yields compare favourably with the corn yields on surrounding non-disturbed land.

Stop 3: TCG Materials Limited
by S.B. Lowe[1]

TCG Materials Limited currently owns 21 licensed properties in southern Ontario with an annual production of approximately 2 million tonnes of sand and gravel. Progressive rehabilitation of 100 ha by the Company during the last 10 years demonstrates that aggregate extraction can be considered as an interim land use. Sites are being returned to agricultural land, conservation and wildlife habitats, and recreational areas.

In Brantford, 1 license includes 3 gravel pits with a combined licensed area of 186 ha and an annual production of 300 000 tonnes, mainly of concrete sand and stone, and road gravel. The pits are clustered along the Grand River, in the northwest part of the city. Although presently rural in nature, this recently annexed area of the city will eventually be developed as an industrial basin.

Following extraction of sand and gravel, worked-out sections of the pits are rehabilitated progressively. To date, approximately 30 ha have been progressively rehabilitated. Final grades are restored either by filling or levelling, soil is replaced, and vegetation established. Wherever possible, agricultural crops are being grown, in order to keep the land productive until it is developed for industrial purposes.

The main pit has been in operation since 1915 and is now largely worked out. It houses the processing plant, stockpiles, and silt ponds, while the neighbouring Cornell pit is the predominant extraction area. Both illustrate agricultural rehabilitation in various stages. A third pit, the Johnson pit is presently being used as a dump for clean fill.

GEOLOGY

The geological setting of the TCG Materials pit is similar to that at Stop 2 (Standard Industries Limited), as both are located in the Grand River spillway. Since the TCG pit is located farther away from the sediment source, gravel-sized material is generally finer than in the previous pit, although the overall gravel content ranges up to 80%. Faces in the pit have a height of approximately 9 m. The dominant lithology found in the gravel is dolostone, with lesser amounts of limestone, minor amounts of siltstone and Precambrian rocks, and rare occurrences of chert. A complete range of specification aggregate products are produced from this site.

CORNELL PIT

Progressive rehabilitation underway in the west end of the Cornell pit (Photo 9) over the last 4 years illustrates the efficiency of soil stripping and replacement when worked-out areas of the pit are available close by. Each year soil is stripped from 1 to 2 ha of the cornfield to the north and replaced on the pit floor, approximately 100 m away (Photo 10). In this portion of the pit the face is relatively shallow (3 to 5 m), and the pit floor consists of clay. Before replacing the strippings, some grading is carried out to establish good drainage, and ripping with a bulldozer may be necessary to relieve areas of compaction.

Machinery used for stripping depends on availability at the time. Where possible, the Company's TD25 bulldozer is used. This allows for better separation of topsoil from subsoil (Photo 11). Topsoil (the "A" horizon) is approximately 30 cm deep, and subsoil (largely the "B" horizon) is approximately 60 cm deep and is extremely stony. When using front-end loaders, separation of these 2 layers is usually not as effective.

For the last 3 years the stripped soil has been moved and spread on worked-out areas of the pit floor without being stored. Additional topsoil and subsoil is also being spread from earth berms established during earlier years of stripping.

Rehabilitated areas are all fertilized with 5-20-20 (5% nitrogen, 20% phosphorus, and 20% potassium) fertilizer or 8-32-16 fertilizer and are usually seeded with birdsfoot trefoil and red fescue or tall fescue. This grass/legume mixture requires little maintenance and acts as an attractive and effective "cover crop", controlling surface erosion and growing a vigorous root system which helps to improve soil structure. Rye may be sown in the fall as a temporary cover crop over the winter.

With the addition of 3 to 4 more ha in 1983, the west portion of the pit will become a field of approximately 8 ha. The cover crop will be worked under and the land evaluated for planting a hay crop or grains. Limitations on production here mainly result from the stones, which will have to be picked mechanically.

In some areas of the pit, agricultural production is not possible because of the topography or the stony nature of available soils. These areas are being revegetated with permanent cover crops, to control erosion, improve the appearance of the area, and help to control dust.

MAIN BRANTFORD PIT

In the main pit (Photo 12), grades have been restored by backfilling a 9 m high face with construction waste followed by spreading 60 cm of subsoil and 30 cm of freshly stripped topsoil. The final slopes are relatively gentle (10 to 15%) and allow easy passage of farm machinery, but are too steep for production of row crops such as corn. This is the first area returned to agriculture by the Company, and all agricultural work was carried out according to normal practices by a local farmer.

Following an initial crop of winter wheat planted in the fall of 1976 and harvested in 1977, a mixture of alfalfa, bromegrass, and clover was established for 4 years of hay production (Photo 13) before being ploughed under (Photo 14), in preparation for planting fall wheat, to be harvested in 1982 (see Chronology).

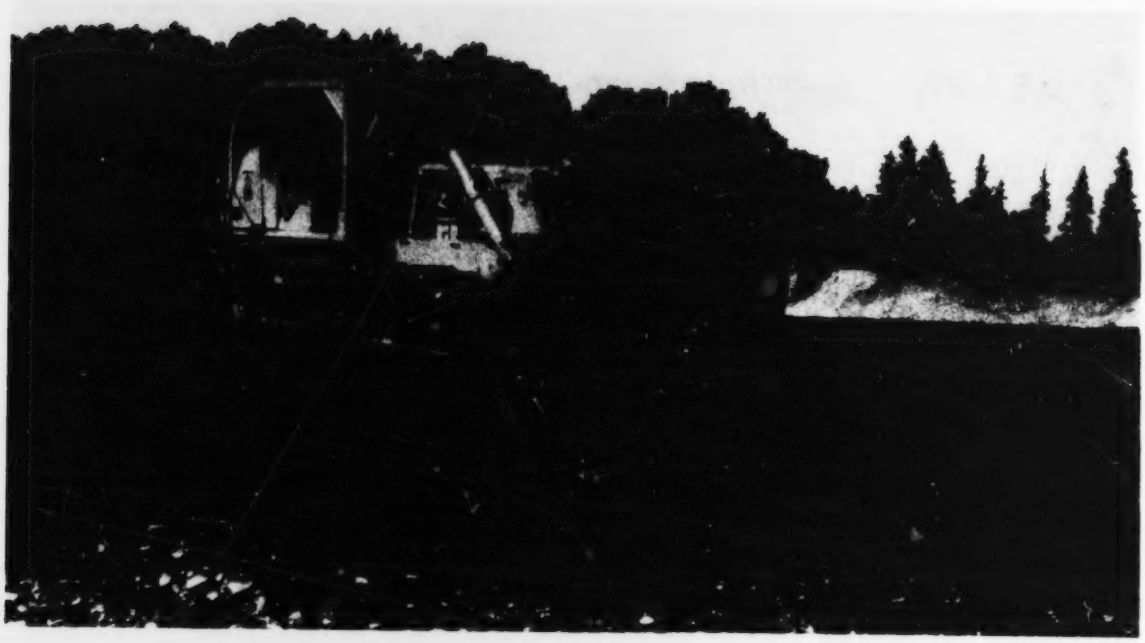
[1]Supervisor, Rehabilitation and Property Improvement, TCG Materials Limited.

OGS 10 587

Photo 9—Progressive rehabilitation (Cornell pit, 1982). Stripped and working acreages of an active pit are kept to a minimum by revegetating worked-out areas of the pit floor.

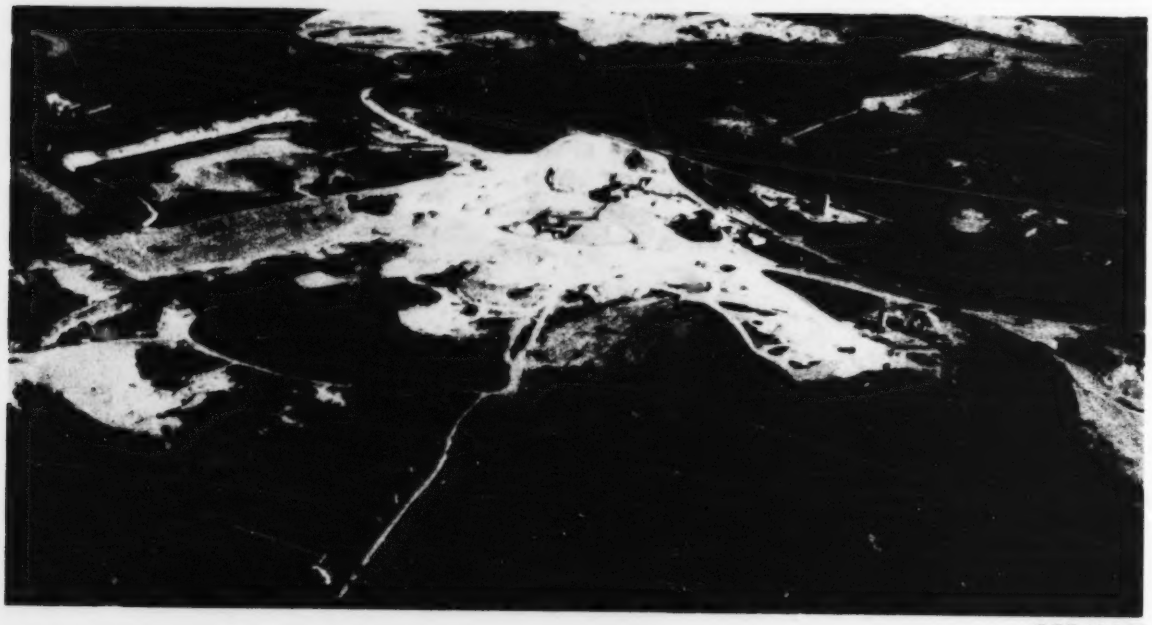
OGS 10 588

Photo 10—Soil stripped for current year's extraction is placed to rehabilitate the pit floor (Cornell pit, 1982).



OGS 10 589

Photo 11—Subsoil and topsoil are replaced in separate layers on the pit floor, a key factor for successful crop production (Cornell pit, 1982).

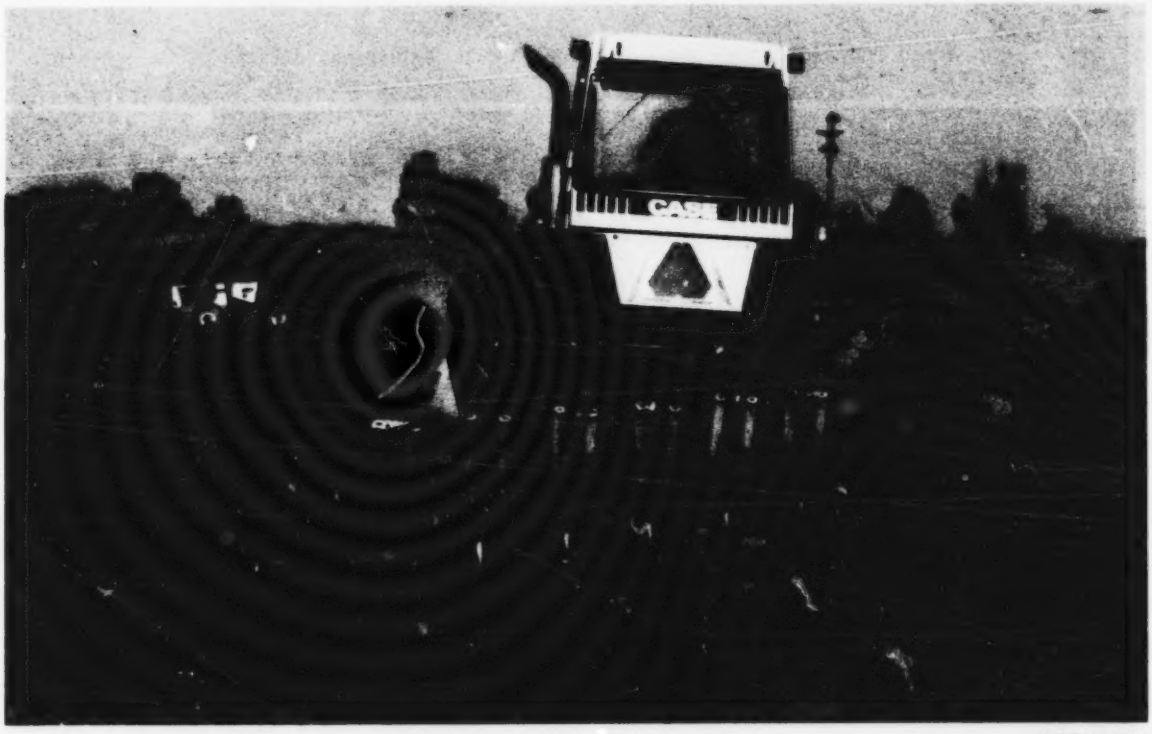


OGS 10 590

Photo 12—Progressive rehabilitation (Brantford main pit, 1979). An 8 ha field producing crops coexists with the processing plants, stockpiles, and settling ponds.

OGS 10 591

Photo 13—Crop production on rehabilitated land. Alfalfa/bromegrass with yields of hay matching neighbouring undisturbed fields (Brantford main pit, 1980).



OGS 10 592

Photo 14—Ploughing-under alfalfa in preparation for a grain crop, 4 years after rehabilitation of the land (Brantford main pit, 1981).

Yields of hay have been satisfactory. In 1980 the first cut yielded 4788 kg/ha, comparable with yields on undisturbed land in the county. The initial crop of wheat was 70% of the average in the area, and the second crop was expected to be much better following the 4 years in hay which served to improve the soil structure and fertility. However, a severe winter in 1981/82 seriously damaged all wheat crops in the county and so the potential of this field has yet to be truly tested. The Company is hoping that the next time the field is put back in wheat there will be a good crop year and yields will be comparable with surrounding farms. Meanwhile, the land is back in hay for 2 or 3 years to continue building up soil conditions.

The Company's experience with this field illustrates the importance of both soil management and crop selection in restoring land to an adequate level of productivity. The main limitation to production has been soil fertility. Normal farming practices may not supply an adequate amount of fertilizer for crop production on recently restored soils, so soil samples are sent away for analyses and precise fertilizer recommendations. A leguminous crop such as an alfalfa mixture is chosen for the first few years on rehabilitated areas to help build up soil conditions and prepare the land for subsequent plantings such as grain crops. This initial period of soil and crop management may last 3 to 5 years before satisfactory levels of fertility and soil structure are once again established, leading to good crop yields.

Chronology: Rehabilitation to forages and wheat crops, Brantford main pit

1915-1975
Sand and gravel extracted to a depth of up to 9 m.

1974-1976
First area in southeast part of pit filled in with construction waste and sloped off from edge of pit down to level of pit floor.

1976
60 cm of stored subsoil replaced and graded.
30 cm of freshly stripped topsoil replaced and graded.
Fertilized with 9-23-30 at 224 kg/ha (200 pounds per acre) and planted with winter wheat in the fall.

1977
Fertilized at 185 kg/ha (165 pounds per acre) in spring.
Wheat harvested at 2345 kg/ha (35 bushels per acre) compared with average on surrounding lands of 3350 kg/ha (50 bushels per acre).
Area expanded from 2.8 ha to 6.0 ha.

1978
Total area fertilized with 18-18-18 at 180 kg/ha (160 pounds per acre) and seeded with hay: bromegrass, 50%; red clover, 25%; and alfalfa, 25%; with a cover crop of oats which was harvested in the fall.

1979
One cut of hay taken in late June, yielded 2408 kg/ha (2150 pounds per acre), compared with approximately 4480 kg/ha (4000 pounds per acre) on undisturbed lands.
Fertilized with 30-0-20 at 168 kg/ha (150 pounds per acre).

1980
First cut of hay was good, yielding 4788 kg/ha (4275 pounds per acre), comparable with yields on undisturbed lands in the area. The second cut was less, at 1633 kg/ha (1485 pounds per acre). Soil samples taken in May showed potash deficiency, and fertilizer was applied: 0-0-60 at 168 kg/ha (150 pounds per acre).

1981
Hay yields were somewhat lower, at 3427 kg/ha (3060 pounds per acre). Soil samples still showed potash deficiency. Alfalfa was ploughed under, fertilized with 9-24-30 at 190 kg/ha (170 pounds per acre), and seeded in the fall with wheat.

1982
Fertilized in spring with 30-0-20 at 280 kg/ha (250 pounds per acre) and undersown with hay (alfalfa and timothy).
Wheat harvested yielded 1910 kg/ha (28.5 bushels per acre), comparable with undisturbed land in the area. (Winter of 1981/82 severely damaged all wheat crops in the area).

CONCLUSIONS

Experience gained in the Company's Brantford pits as well as other properties has helped them to evaluate several important steps that they feel need to be followed carefully if agricultural rehabilitation is to be successful. Wherever possible TCG Materials Limited tries to carry out the following:

1. Establish final grades on pit floor or filled area to allow for adequate drainage.
2. Replace and spread at least 30 to 60 cm of subsoil. This cover is especially important when pits are filled in with waste materials.
3. Replace and spread 30 cm of topsoil, preferably freshly stripped.
4. Establish a leguminous forage crop (e.g. alfalfa) for several years.
5. Follow good farming practices, taking special care in fertilization (i.e. fertilization program should be based on soil tests). If necessary, use higher levels of application than is normal on undisturbed lands.

From TCG Materials Limited, proceed into Brantford and join Highway 2. Travel east on Highway 2 and 53 to Hamilton. Between Brantford and Hamilton pass over the Haldimand Clay Plain. The clay plain is essentially level, consisting of clay deposited in glacial Lake Warren (Cowan 1972) which formed approximately 13 000 years B.P. during the waning stages of the Port Huron Stadial. Along Highway 2 and 53 the plain is interrupted by valleys associated with Fairchild Creek and Big Creek. These valleys

have silty alluvium deposits in them. Near Hamilton, join Highway 403. At kilometre 142 is the Highway 403 roadcut. The same strata that were exposed at Clappisons Corners roadcut are exposed here, with the addition of the Eramosa Member of the Lockport Formation being exposed at the top of the section and the Cabot Head Formation at the base of the section. The Eramosa Member is the first exposure observed while going down the hill and can be observed at the Mohawk Road interchange. The Eramosa Member is usually a dark brown or black, bituminous dolostone overlying the Vinemount shale beds and the Goat Island dolostone. The Cabot Head grey and green shales are exposed near the base of the section underlying the red sandstones and shales of the Grimsby Formation.

From the Highway 403 roadcut a good view is gained of the Dundas Valley, with the Town of Dundas and the City of Hamilton located within it. Proceed east on the QEW and turn north on the Guelph Line (Halton Road 1) and ascend the Niagara Escarpment to Stop 4, the Nelson Aggregate Co., at kilometre 171.

Stop 4: Nelson Aggregate Co.

Nelson Aggregate Co. consists of 5 major sites: Nelson quarry, Limestone quarry, Lincoln quarry, Oneida quarry, and Oak Park pit. The normal annual production of aggregates from these sites is around 5 million tonnes. This makes Nelson one of the largest aggregate producers in Ontario.

NELSON QUARRY

The Nelson quarry is strategically located to serve one of the largest market areas in Canada (Toronto-Hamilton). The company produces a wide range of sizes from finely ground agricultural limestone to large armour stone, used for lakeshore protection.

GEOLOGY

The quarry was established in 1954 in the Niagara Escarpment, 8 km north of the centre of Burlington on the Guelph Line in the Amabel and Reynales dolostone formations (Photo 15). The quarry face averages 17 to 18 m and the yield per hectare is approximately 160 000 tonnes.

The upper part of the Amabel Formation in this area is characterized by many reefs. Associated with the reefs are dipping beds on the flanks of the reefs. Below this upper reefal facies is a 5 m thick zone of horizontally bedded dolostone with no reefs present. The reefy dolostone at the top of the quarry face causes the bedrock surface to be irregular in the area of the quarry. The irregular bedrock surface can pose problems for overburden stripping.

The Amabel Formation in this area may be described generally as light grey, medium crystalline, medium- to massive-bedded fossiliferous dolostone. The Reynales Formation exposed in the quarry floor consists of medium-buff to grey mottled, aphanitic, medium-bedded dolostone, containing green shaly partings.

Drift cover in the quarry is generally 1.5 m in depth, although, in one area the overburden reaches 11 m. Drift in the area consists of silty Halton Till and glaciolacustrine clay.

The geology and chemistry of the bedrock in the Nelson quarry is described in greater detail in reports by Hewitt (1960, 1968), Hewitt and Vos (1972), and Vos (1969).

QUARRY OPERATION

Production of aggregates at the quarry begins with stripping the bedrock of all overburden. Following this, blast holes are drilled and explosives are set. Large blocks of rubble resulting from the blast are set aside and classified by weight for use as armour stone for shore protection (Photo 16). The remainder of the rubble is loaded by an electric-powered 5.4 m^3 shovel onto 45 tonne and 32 tonne trucks (Photo 15). The rubble is reduced by a 106.7 cm gyratory crusher to a size of 15.2 mm and conveyed to a surgepile. Stone used for rip rap is separated at this time. The remainder of the stockpile is passed through a secondary crusher and screens to produce products of various sizes and gradations. The various products are stored in stockpiles which are located over reclaiming tunnels. Customer orders and dispatching are processed through an on-site microcomputer. All haulage from the quarry is by truck. Much of the aggregate produced in the quarry is used for concrete as well as asphalt. A 6365 kg Cedarapids asphalt batching plant, located on the quarry site, is capable of producing up to 544 tonnes per hour.

REHABILITATION

There is a total licensed area of 220 ha with 80 ha extracted and 140 ha remaining to be extracted. A total of 60 ha have been rehabilitated. The average annual production in recent years has been approximately 2 million tonnes, and a total of 48 million tonnes of crushed stone has been produced since 1954. This makes the Nelson operation one of the largest in Ontario.

There are 3 major features of the Nelson quarry that merit detailed consideration: the trout pond, pastureland, and backsloping, seeding, and treeing.

Trout Pond

In constructing the pond, an area of approximately 0.2 ha was extracted below the quarry floor to a depth of 3 m. The area was seeded and trees were planted around the pond (Photo 17). The basic function of the pond is as a

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Photo 15—Quarry face exposing 20 m of Amabel Formation dolostone. Loading is by a 5.4 m³ P & H model 1600 electric shovel and a 5 m³ loader, with haulage to the plant by three 45 tonne and one 32 tonne haul trucks.

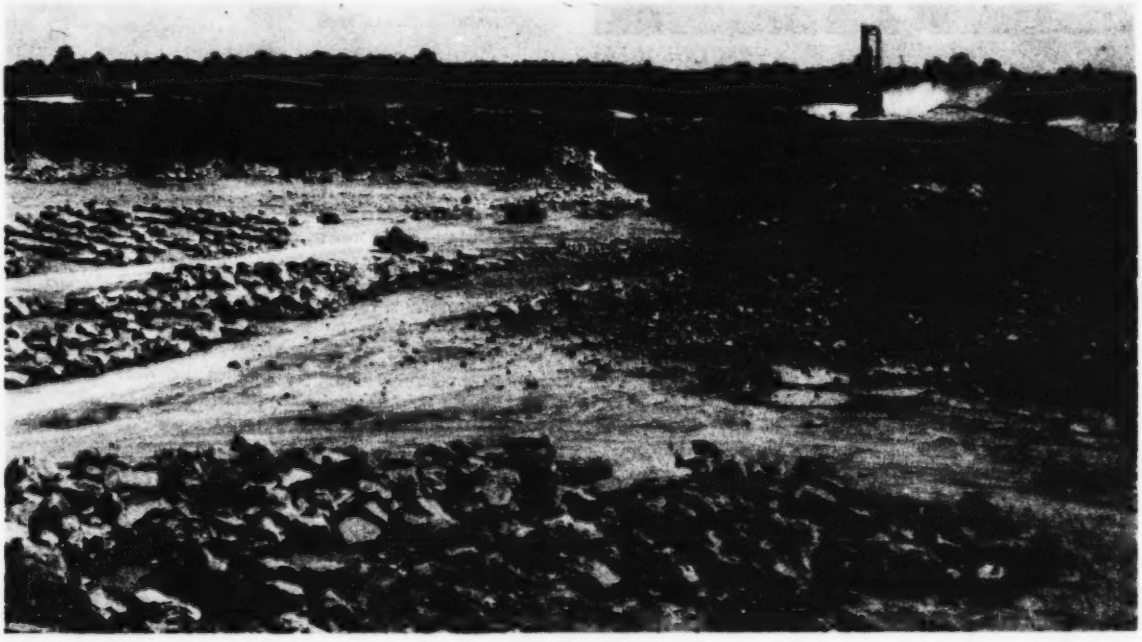

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Photo 16—Quarry operation with stripped area and quarry face. Armour stone is being placed in rows for delivery to customers.

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Photo 17—The Nelson quarry trout pond in the foreground with poplar and willow trees surrounding it. In the background are the operating plant and product stockpiles.

pumping station to keep the quarry floor dry at all times for dry extraction methods. Its use as a trout pond is secondary. The pond is stocked with approximately 800 rainbow trout of various sizes. The healthy fish are positive proof that the quarry is not a cause of water pollution.

The pond area and surrounding marshy areas full of bulrushes (cattails) are also a natural habitat for the Canada goose (*Branta canadensis)* and various species of ducks, especially the mallard, gadwall, and pintail. Contrary to the belief that aggregate extraction operations ruin wildlife habitat areas, once the wildlife understand the operation (i.e. that they will not be harmed) they are not afraid, as evidenced by the deer, geese, and ducks in pits and quarries. Mother ducks and their broods frequently walk across paved roads in front of 40 tonnes Euclid trucks fully expecting the trucks to slow down and wait until the crossing is completed.

Pastureland

In the spring of 1973, the Nelson quarry started to develop pastureland on the filled slopes of the quarried area (Photo 18). They now have approximately 6 ha in pasture. The back slopes are part of a continuous program that follows along immediately behind the working face of the quarry.

The overburden being stripped from the top of the dolostone *in situ* is transported to the quarry face and dumped. Then 5 to 8 cm of topsoil are placed over the overburden (this is the minimum to maintain grass) and fertilizer is applied. Topsoil is usually scarce and its use should be well planned. Any topsoil that has been compacted in large piles for more than 1 year will lose much of its nutrient and microorganisms, thereby reducing its quality. This continual rehabilitation process practiced at Nelson quarry prohibits the topsoil from losing its nutrient and microorganic properties. The fertilizer used is 5-20-20 at approximately 450 to 560 kg/ha (400 to 500 pounds per acre) per year. The slope is 3:1 and there is no subsidence. The back slopes are vegetated in grass using the following seed mix:

Creeping Red Fescue (*Festuca rubra L.)*	33%
Bromegrass (*Bromus inermis Leyrs)*	29%
Annual Rye Grass	17%
White Clover (*Trifolium repens L.)*	4%
Companion Crop (ryegrass)	17%

On the back slopes 12 beef cattle are grazed each year from April to November.

Backsloping, Seeding, and Treeing

The principal purposes for vegetating a quarry face are landscaping, the encouragement of wildlife, and the control of erosion. There is some erosion on the new slopes each year after the first winter. This is a result of the seed spread in September not being able to stabilize the soil over the first winter. There are large numbers of 5 to 10 cm stones remaining in the overburden and topsoil, and this no doubt aids the erosion. The Company feels that this is not a major problem and hand broadcasts the eroded areas. After the second winter the erosion is no longer evident.

Nelson estimates the cost of filling, seeding, and treeing, to be in the order of $36 300 per ha including maintenance costs. This figure appears to be high because it is the cost for the backsloping. It does not include the total area of 60 ha which is considered rehabilitated (part of this is the quarry floor which needs no attention). Nelson is actually building a shoreline in the backsloping process because the area will eventually be an artificial lake which will cover the entire quarry. The depth of the lake will be approximately 6 m and Nelson has purposely varied the backsloping area so it will eventually form an attractive, irregular shoreline. The average cost of rehabilitating, including the area needing no attention, is approximately $5000 per ha. There may be some problems

when the vegetated, treed area is flooded (stabilized to natural water table level) because as this vegetation decays some of it may float to the surface. The Company would be well advised to seek opinions on the problems that may result if the vegetation is not removed before flooding because the costs of maintenance crews to clean the decayed vegetation from the surface of the lake could be far more costly than removal before flooding.

The Company maintains a full-time nursery staff and has several tree nursery plots for eventual transplanting on the slopes. Orginally the Company planted many lombardy poplars and willows which are particularly suited to the soil conditions associated with pits and quarries. The nursery has now expanded and includes many tree species, notably spruce and cedar.

The quarry has occasionally been blamed for lowering the water table in the surrounding area. Nelson quarry personnel continually test the water levels around the perimeter of the property using test holes. Weekly readings from these holes continue to prove that water levels in the surrounding water wells have not been lowered or interfered with in any way. The Ontario Ministry of the Environment and the Ontario Ministry of Health also test the water.

The Company believes that there is nothing particularly sophisticated about their procedure of progressive rehabilitation and they are constantly trying new ideas and techniques. The Nelson Aggregate Co. is clearly interested in the practical side of rehabilitation.

From Nelson continue north and descend the escarpment. Pass through Lowville, and then head east on Halton Regional Road 7. Pass to the south of Rattlesnake Point which is part of a section of the escarpment known as the Milton Outlier. Continue east to Milton, passing over the Halton Till Plain. Drive into Milton via Highway 25 to Stop 5, Consumers Glass Company Limited, at kilometre 201.

Stop 5: Consumers Glass Company Limited, Milton Plant

The Milton glass-container plant (Photo 19) is the newest of Consumers Glass' 5 container plants in Canada. Construction of the $23.5 million plant began in July 1979, and first production was achieved 10 months later on May 1, 1980.

Currently more than 60 different, narrow-necked, type 3 containers, all of emerald green colour, are manufactured at Milton. Many are beverage containers for beer, mineral water, soft drinks, wine, and other assorted uses.

The principal raw materials include silica sand from On-

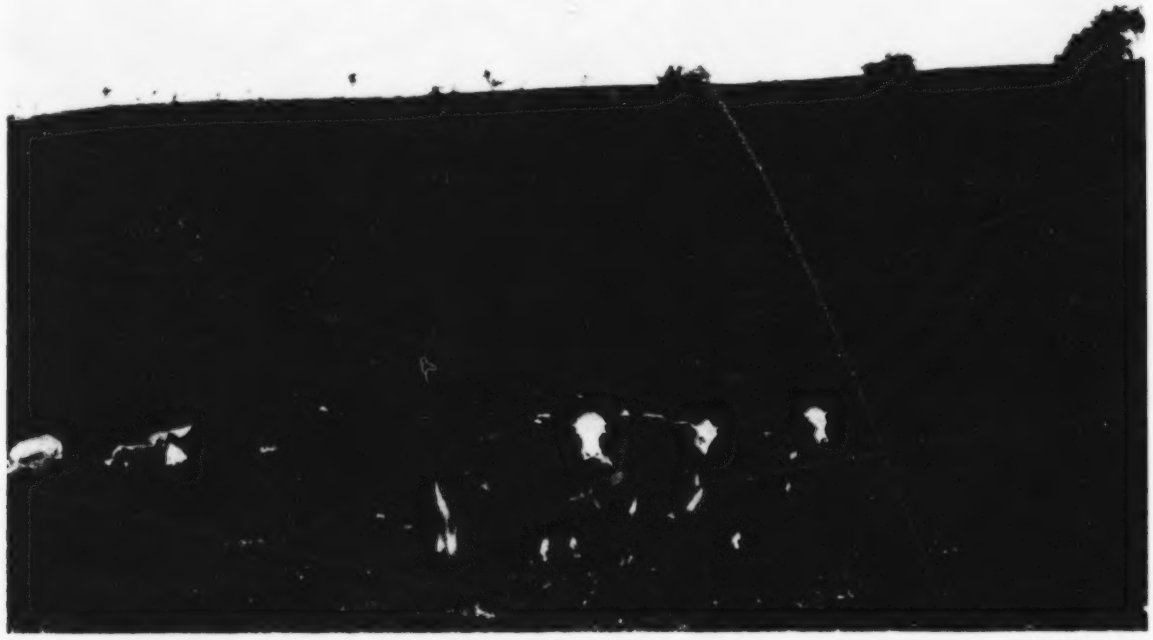

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Photo 18—Pastureland developed on the slopes of the Nelson quarry. Cattle graze the slopes once the slopes are stable.

tario and Pennsylvania, synthetic soda ash from Amherstburg, natural soda ash from Wyoming, and limestone and nepheline syenite from Ontario. Through the years Consumers Glass has participated in gathering programs of cullet (used glass). It is now a significant raw material because the Company previously recognized the environmental and energy-saving benefits of such a practice. The raw materials arrive by rail or truck while all finished products are shipped by truck.

The schematic layout in Figure 4 shows the relationship between the major plant elements.

Raw materials are received at the south end of the complex and elevated into 16 silos and other storage bins. Glass-making ingredients are drawn from the storage facilities through a computer-controlled automatic batching system and, on demand, fed to a day bin and batch charger at the end of the furnace.

The present cross-flow furnace has a total holding capacity of 400 tonnes with a pulling capacity of 250 tonnes per day. The temperature of the melting section of the furnace is held at 1482°C (2700°F), the fining section at 1182°C (2160°F), while temperature at the feeders prior to forming is 1093°C (2000°F).

The glass is formed in any of 3 Hartford machines. The largest is a special Advanced Independent Section (A.I.S.) machine with 8 section triple molds and a sophisticated computer control. The second glass-forming machine is a regular 6 section double mold machine (Photo 20), while the third glass former is a 6 section double mold spread centre machine. All machines are air cooled. Output from the A.I.S. glass-forming machine is about 250 bottles per minute. The middle machine can be converted to either single or double mold capacity and has an output range of from 25 to 120 bottles per minute. Production of the third machine ranges from 60 to 120 bottles per minute.

Finished bottles are transferred, via conveyors, from the forming machines to the annealing lehr. The purpose of the lehr is to reheat the ware to 566°C (1050°F) and then, gradually and uniformly, to reduce the temperature of the glass to room temperature, thereby eliminating damaging stresses in the newly formed glass. Passage through the lehr takes about 1 hour and the time of travel is important to establish optimum strength and durability of the glass.

After leaving the lehr, each container is subjected to visual and automatic inspection checks to identify any im-

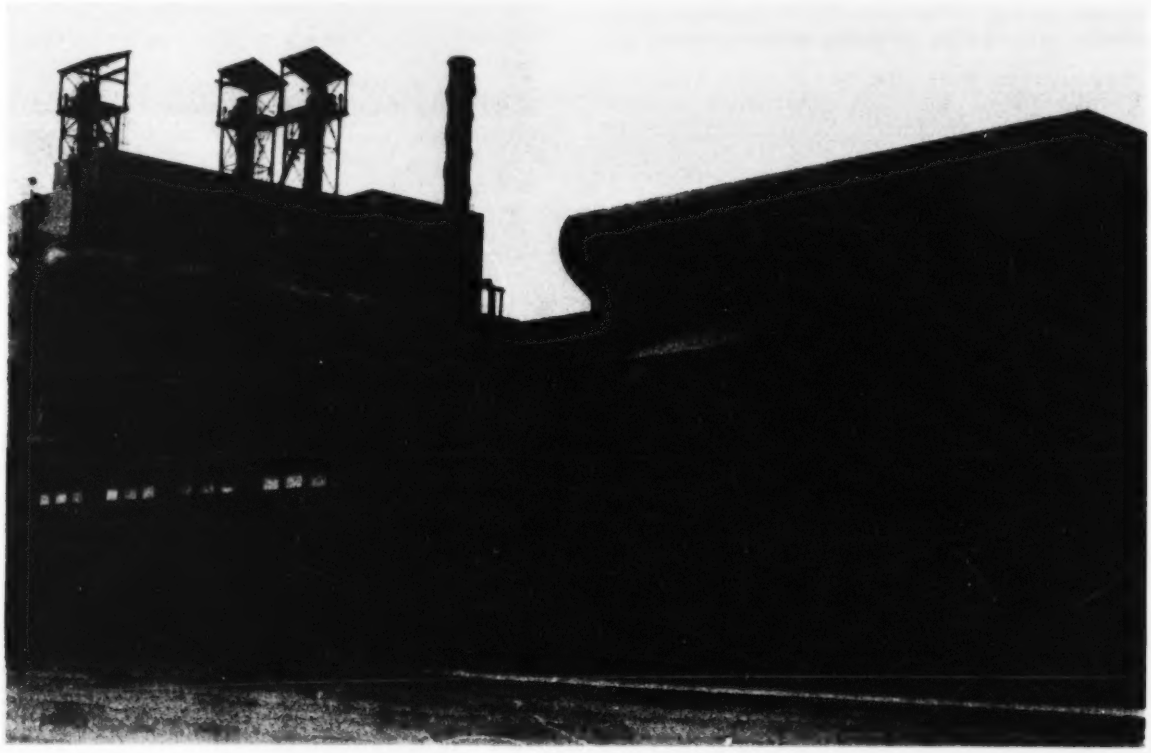

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Photo 19—Consumers Glass Company Limited, Milton plant, showing storage silos, furnace area, and offices.

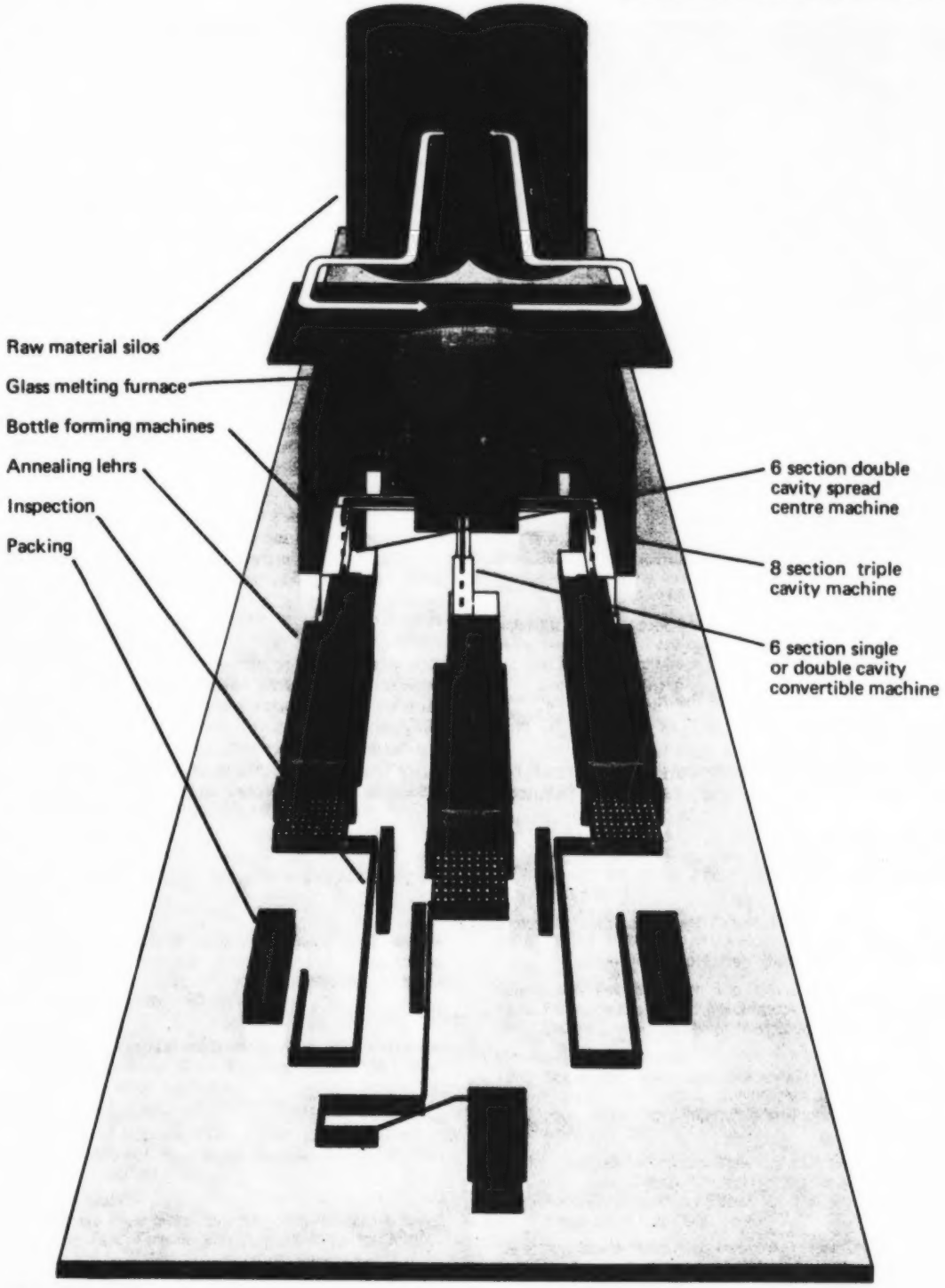

Figure 4—Schematic of the glass bottle manufacturing process (courtesy of the Consumers Glass Company Limited plant, Milton, Ontario).

OGS 10 598

Photo 20—Parison (embryo bottle) being flipped into a finishing mold.

perfections. Containers that fail the rigid inspection are removed from the line, broken, and recycled to the melting furnace.

The glass is then elevated on an "alpine" and conveyed to automatic pallet-packing and semiautomatic carton-filling equipment. This combination of packing options provides great flexibility to cope with changes in product quantities and styles. The average bulk pallet contains 2448 units which can be loaded in trucks for direct customer shipment or moved to storage until required.

The Milton property was originally developed in 1973 to provide additional storage and distribution facilities to serve the Consumers Glass manufacturing plant at Etobicoke, some 40 km to the east. An average of 180 people are presently employed: 29 staff and 151 plant personnel, who work on 4 shifts over a 24 hour day. The plant layout was designed to permit the addition of more parallel glass production lines as required.

Consumers Glass Company Limited was founded in 1917 and for many years produced glass containers at the original plant in Ville St. Pierre, Quebec. In addition to Ville St. Pierre and Milton, the Company has plants at Lavington, British Columbia; Etobicoke, Ontario; and Candiac, Quebec. From these 5 plants, as well as from 10 strategically located warehouses and distribution centres, Consumers Glass supplies many customers in Canada and the United States.

The Company has a technological assistance agreement with Brockway Glass Company, Incorporated, one of the world's most advanced glass container manufacturers, which helps Consumers Glass maintain the very high quality of its products.

From Consumers Glass Company Limited, take Highway 401 east to Toronto. From Highways 25 and 401, a good view is afforded of the Milton outlier to the west. The entire extent of the journey along Highway 401 is on the Halton Till plain. Topography in this area is level, interrupted only by the alluvium-filled valleys of the Credit River and Etobicoke Creek. Return to the hotel located near Toronto International Airport.

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6800